437

THE GCARS SYSTEM
FORTRAN IV PROGRAMMERS MANUAL
PART C - PROGRAMS FOR CONTOUR MAPPING

SEPTEMBER 1969 - NUMBER 27

BY

A. K. TURNER

JHRP
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PURDUE UNIVERSITY AND
INDIANA STATE HIGHWAY COMMISSION

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Final Report (Part III - C)

THE GCARS SYSTEM FORTRAN IV PROGRAMMERS MANUAL
PART C - PROGRAMS FOR CONTOUR MAPPING

by

A. Keith Turner
Post-Doctoral Research Instructor

Joint Highway Research Project

Project: C-36-72A

File: 1-6-1

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Conducted by

Joint Highway Research Project
Engineering Experiment Station
Purdue University

in cooperation with the

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and the

U.S. Department of Transportation
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Bureau of Public Roads

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or the
Bureau of Public Roads

Purdue University
Lafayette, Indiana
September 1969

Final Report (Part III-C)

THE GCARS SYSTEM FORTRAN IV PROGRAMMERS MANUAL PART C - PROGRAMS FOR CONTOUR MAPPING

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To: J. F. McLaughlin, Director
Joint Highway Research Project

From: H. L. Michael, Associate Director
Joint Highway Research Project

Attached is Part III-C of the Final Report on the research project "Evaluation of Numerical Surface Techniques Applied to Highway Location Analysis" which was approved on July 1, 1967. This report has been authored by Dr. A. Keith Turner of our staff.

This report describes in detail and documents the FORTRAN computer programs used by the GCARS System to prepare contour maps of the three dimensional models of the individual or combined highway location factors. Contour maps are prepared on the printer as part of the normal job output, or they can be produced as pen and ink drawings on the CALCOMP plotter. The report is one of a series of four reports documenting the various phases of the GCARS System.

This report is presented to the Board for review and comment and for the record.

Respectfully submitted,

Harold L. Michael /kem

Harold L. Michael
Associate Director

HLM:mz

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NOTICE

These programs have been tested and are believed to be free of errors. If errors are located, the Joint Highway Research Project would appreciate notification.

Send comments to:-

Joint Highway Research Project
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Professor Robert D. Miles, P. E., directed the research project and reviewed the manuscript. His assistance is gratefully acknowledged.

THE GCARS SYSTEM
FORTRAN IV PROGRAMMERS MANUAL
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by

A. Keith Turner

INTRODUCTION

The GCARS System is a computer-aided highway location system. Man-machine communications or "dialogs" are required between the engineer and the computer during all phases of the procedure. Machine-to-man information exchanges must be concise and readily comprehensible if the system is to operate efficiently. In most cases such information exchanges involve the production of both (a) statistical and/or summary data, and (b) graphical displays.

Since the GCARS System utilizes three-dimensional data, procedures for displaying such data were developed. This section of the GCARS System Programmers Manual describes the programs and subroutines used to generate contour maps of three-dimensional data.

a) Machine-Contouring Procedures

Contouring of three-dimensional data may be performed in a variety of ways; the contouring may be extremely literal, extremely interpretative, or a compromise between the two (18)[*]. Interpretative contouring involves considerable "art", since the contour lines do not necessarily honor all the data points equally, but reflect general knowledge of the process by the person doing the contouring.

Most computer-generated maps, including those used by GCARS, give literal contours that honor the supplied data. Some attempts have been made to modify this literal interpretation to favor certain predetermined directions (12). Even with literal contouring procedures, the results obtained are dependent on the method used to interpolate between points of known value. As a consequence, computer-generated maps are not "unbiased", as is often believed by the unwary, but are in fact strongly and consistently biased according to the interpretation of the data.

---

[*] Numbers in parenthesis refer to references.

As a consequence, the computer-generated contour maps developed by these routines may not be equally suitable for all applications. They are extremely useful as "quick-look" maps to give the user a general idea of his data, or to check the general validity of the data. Furthermore, since all maps are made consistently, they can also be used for comparison purposes. Contouring several data sets by humans inevitably involves some learning processes which introduce an uncertain and subtle bias into the results rendering comparison of maps difficult. In contrast, the computer will not "learn" from one problem to the other, but will handle each data set uniformly.

Contouring involves identifying and connecting a sequence of points having a certain value. It therefore involves searching the data for areas having these elevations, and then computing the location of the contour line. The only convenient way to do this on the computer is to use gridded data - a series of "elevation" values of the dependent variable being contoured on a suitably scaled square lattice.

Computer contouring therefore generally involves two steps:

(1) conversion of irregularly spaced data observations defined by X, Y, and Z coordinates to a suitable matrix of Z-values.

(2) interpolation within grid squares to locate the contour lines.

If the data is already in grid form, the first step can be omitted. This is not a common occurrence however. A large number of interpolation procedures have been proposed including:

(1) fitting of a suitable regression model to the data and contouring the regression surface.

(2) fitting of "local polynonials". This involves the computation of a series of small regression models utilizing nearby data points, and then using these regression surfaces to estimate the value at the grid points.

(3) use of weighted moving-average procedures. These compute an average of a certain number of nearby points with each weighted according to its distance to the grid point being evaluated.

Weighted moving-averages are generally computationally easier, and therefore faster, than the other methods. Few quantitative comparisons between the various methods are possible. Various workers prefer certain techniques based on their experiences. The weighted moving-average procedures were used extensively by GCARS. Subroutine GRID, based on a program developed by Professor W. R. Tobler at the University of Michigan, uses a weighted moving-average algorithm to determine grid values. As in all interpolation procedures some smoothing of the data results from its use. A limited amount of testing suggests that the smoothing is normally less than 2% of the data range, rising to nearly 10% of the range only with extremely erratic data.

b) Computer Display Devices

Graphical displays can be developed by computers utilizing the standard character printer or one of the specially designed display units such as incremental plotters, drafting machines, or cathode ray tube viewers.

The use of the "on-line" character printer often has advantages, particularly in the initial stages of an analysis. First, the graphical output is produced by the printer as part of the regular job output and is available concurrently with the analysis. Second the printer is economical to operate and relatively fast (600 to 1200 lines per minute). Third, because the printer is an "on-line" device it does not require the use of magnetic tapes, which are needed when the CALCOMP plotter is used, thus reducing the chances of human error.

Purdue University has an "off-line" 30-inch drum-type CALCOMP plotter. Use of the CALCOMP plotter is justified when plots of superior quality are desired. The resolution of the printer is limited by line and character spacing. Since these are unequal, distortion may occur; although this can be avoided by careful planning of the display scale (see page C-14). In contrast the plotter has no distortion and a resolution governed by its step size - 0.01 inch. Thus, it can produce ink drawings suitable for inclusion in reports.

METHOD OF OPERATION

Figure 1 shows the interactions between the various routines described in this part of the Programmers Manual. Subroutine PRTCON4 which prepares contour maps on the printer, and Subroutine GRID which interpolates irregular to gridded data, are utilized by several portions of the GCARS System (13, 14). They may also be used to prepare maps of data in conjunction with Program MAPPER, as shown in Figure 1.

The CALCOMP contouring program, Program CONTUR and its associated subroutines, is a semi-autonomous sequence of routines which accepts punched-cards containing the gridded values of the surface to be contoured.

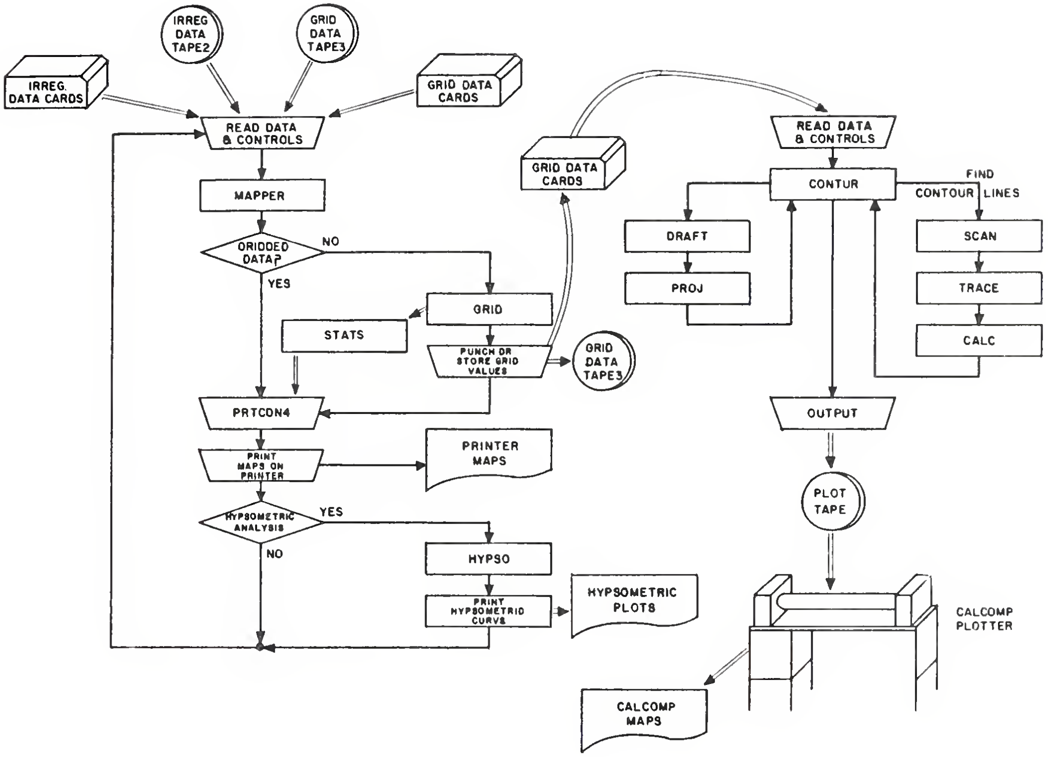


FIGURE I. GCARS CONTOURING PROGRAMS.

Subroutine STATS is a utility subroutine which computes statistical measures of data arrays. The routine determines the maximum and minimum values of the data, and computes the mean, standard deviation and variance. It is widely used in the GCARS System.

PRESENT CAPACITIES, OPTIONS, RESTRICTIONS

a) Size of Matrices

The GCARS System, as presently developed, has been standardized to work with 50 x 50 matrices. Neither dimension can exceed these limits without correcting the DIMENSION statements in the programs. Changes in shape, for instance to 100 x 25, can be accomplished without increasing the overall storage requirements.

Subroutines GRID, PRTCON4, and STATS automatically change their matrix dimensions to coincide with those of the calling program. These programs have been successfully run with matrices dimensioned 100 x 100. However, due to limitations in the width of standard computer paper, PRTCON4 cannot contour matrices with more than 64 columns in a single pass.

b) Irregularly-Spaced Data

Subroutine GRID can make interpolations onto a grid for a maximum of 1000 irregularly spaced data-points at a time. If more than 1000 data-points are located within a desired area, it must be subdivided into a series of subareas each containing no more than 1000 points, and the data must be presorted into appropriate data subsets. If the chosen subareas are overlapped, the gridded values for each subarea can be combined to give an overall grid. Program MAPPER is capable of pre-sorting the data for any area into a number of subareas before calling GRID. It checks to see if the subarea contains less than 1000 points.

c) Input Options

Program MAPPER can be supplied with either gridded or irregular data on either cards or tape. Program CONTUR requires card data.

d) Output Options

Subroutine GRID can punch out gridded values or store them on tape. Many display and contouring options are available in both PRTCON4 and CONTUR.

METHOD OF COMPUTATION

a) Program MAPPER

Program MAPPER has been developed to produce contour maps on the printer for either gridded or irregularly spaced data. The maps are produced by Subroutine PRTCON4, which required gridded data. Thus if the data is not gridded, MAPPER first calls Subroutine GRID to interpolate the irregularly spaced data onto a suitable grid.

Figure 2 is a flowchart of Program MAPPER. The program reads the first control card to determine the type of data (gridded or irregular) and branches accordingly. In either case the input data may be supplied on cards or on tape. In accordance with the GCARS standards, irregular data is supplied on a tape labelled TAPE2, and gridded data on a tape labelled TAPE3. (An option within Subroutine GRID allows the user to request the interpolated grid values be stored on a TAPE3 user tape).

For computational efficiency the number of irregularly spaced observations being interpolated at any one time is limited to one thousand. The total running time of Subroutine GRID depends on the number of searches and comparisons it has to make. The number of comparisons is the product of the number of grid points being evaluated and the total number of original data points.

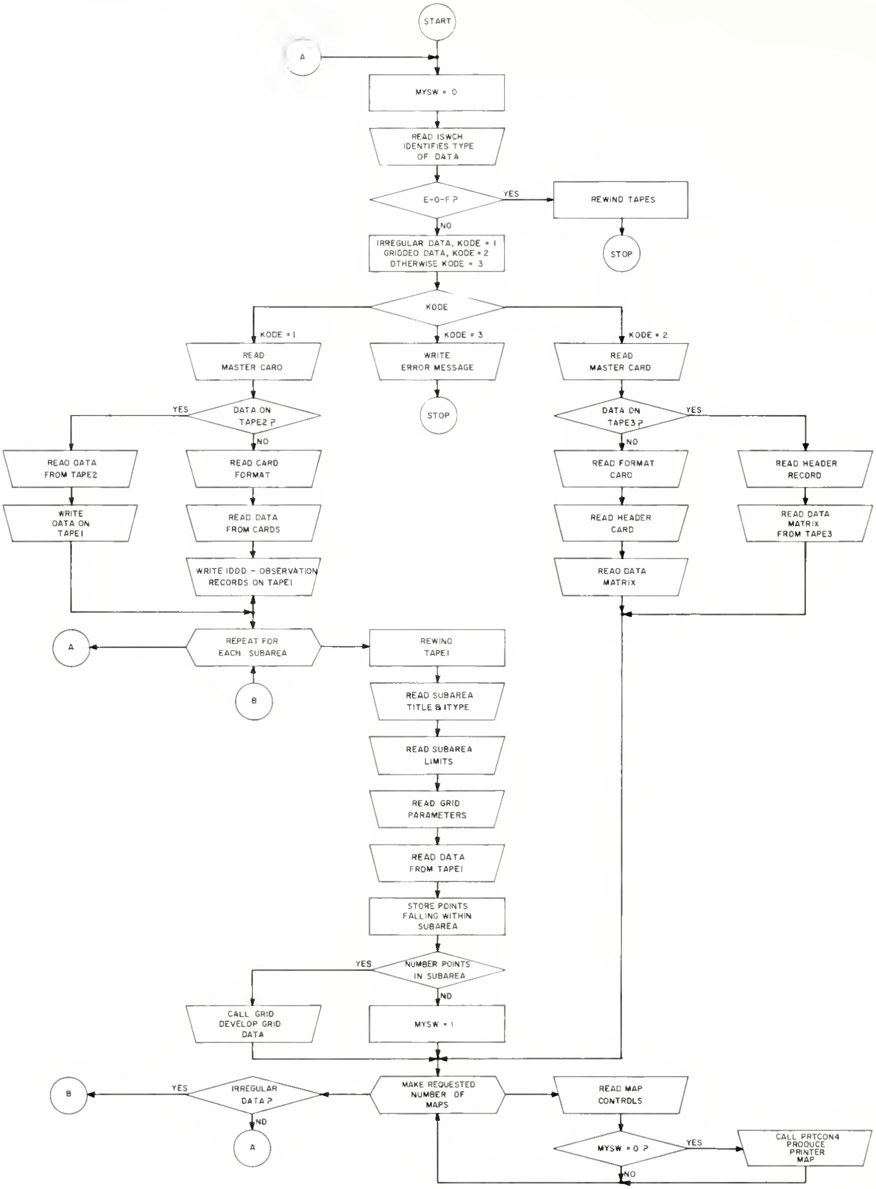


FIGURE 2. FLOWCHART FOR PROGRAM MAPPER.

Accordingly, Program MAPPER allows for the specification of several overlapping subareas and "pre-sorts" the new data to locate those points falling within each. The total is checked. If it exceeds 1000 points an error message is printed and further analysis of that subarea is abandoned. The resulting output will consist of several card decks and printer maps, which can be combined to form a single gridded array and a single map of the whole area (Programs for this step are left for the user to develop). Once a single array has been produced it can be resubmitted to produce overall maps of the area.

After the data have been prepared, the two branches of Program MAPPER converge and Subroutine PRTCON4 is called to produce contour maps of the data. Multiple maps of the data can be produced. These may be different or identical. If identical maps are desired, the word "SAME" must appear on the appropriate control card, and then only one set of map control cards are required. Otherwise the number of map control card sets must equal the number of maps requested. Details of the various control cards are given on page C-30 as part of the listing of Program MAPPER.

b) Subroutine GRID

The documentation for an interpolation algorithm and a MAD language program were obtained from Professor W. R. Tobler, Geography Department, University of Michigan, Ann Arbor. The MAD language program was translated into FORTRAN IV and forms the basis of Subroutine GRID within the GCARS System.

The algorithm is used whenever irregularly spaced observation, each defined by X, Y, and Z-coordinates, are interpolated to produce a matrix of X-coordinate values, corresponding to the positions of a series of observations on a regular lattice.

When using Subroutine GRID, the operator may define the limits of the area over which interpolation is to be performed, or the routine can search for the limits of the area defined by the data and use these as the interpolation boundaries. The actual spacing of the lattice can be defined by the operator. Otherwise the program will compute a "best" grid size which approximately equals the square root of the area divided by the number of observations. This procedure is described in detail below. Since the interpolation boundaries, the grid sizes in the X and Y directions, and the number of columns and rows computed or defined for the matrix are all mutually inter-dependent, some readjustments may be required.

The algorithm involves a weighted moving average procedure, and appears to give results which are comparable to those obtained by the fitting of local polynomials, but is computationally much simpler. Following considerable (empirical) testing, the main disadvantage appears to be a slight dampening (or smoothing) effect on the data. This approaches 10% of the data range for extremely erratic data, but for commonly encountered data distributions is much less, one or two percent smoothing being normal. Competing schemes are described in the references (1, 4).

The following discussion was obtained from Tobler. It includes a description of the procedure for defining an optimum grid size.

An observation is recorded as X_i, Y_i, Z_i, $i = 1, \ldots, n$, where X, Y are locational coordinates and Z is a value at X, Y. Lattice points are labelled jk in standard matrix notation (j = row subscript, and k = column subscript). The problem is to estimate Z'_{jk}.

This is accomplished in the following steps:

(1) Calculate A, the area of the rectangle bounded by the maximum and minimum of the coordinate values X and Y.

(2) Let the grid size, G, equal the square root of the area divided by the number of observations,

$$G = (A/n)^{\frac{1}{2}}$$

(3) The number of rows in the matrix is computed as the (truncated) integer part of

$$R = (\triangle Y/G) + 1.5 \quad \text{where } \triangle Y = \text{range in } Y$$

and the number of columns as the integer part of

$$C = (\triangle X/G) + 1.5 \quad \text{where } \triangle X = \text{range in } X$$

This yields a matrix which has approximately N entries.

(4) In general, because of truncation,

$$(C - 1) * G \neq \triangle X$$

$$(R - 1) * G \neq \triangle Y$$

Split the difference, letting

$$\triangle' X = (\triangle X - (C - 1) * G)/2$$

$$\triangle' Y = (\triangle Y - (R - 1) * G)/2$$

and assign X and Y coordinates to positions in the matrix. For example the j^{th} row and the k^{th} column will have the coordinates

$$X_k = X_{min} + \triangle' X + (k - 1) * G$$

$$Y_j = Y_{max} - \triangle' Y - (j - 1) * G$$

(5) For each position in the matrix calculate the square of the distance to each observation using

$$D_i^2 = (X_k - X_i)^2 + (Y_j - Y_i)^2$$

and rank the points in order of increasing distance from the jk^{th} lattice point as they are computed, saving the results for only the nearest six points, except if $D_i^2 < \epsilon$ in which case set $Z'_{jk} = Z_i$ and proceed to the next position in the matrix since the assignment has been completed. (ϵ has been arbitrarily set = G/25. This means that if any data point is as close or closer than 1/25 of the grid size to a lattice point, the lattice point is assumed to be adequately defined).

(6) Assign a value to the jk^{th} position by computing the weighted mean as follows:

   (a) compute the weighted mean of the nearest six points as the sum of the elevations divided by the square roots of their distances to Z'_{jk}, divided by the sum of one over the square roots of these distances.

   (b) average this weighted mean with the value of the nearest of the six points. The algorithm may be written as

$$Z'_{jk} = \frac{Z_n + \dfrac{\sum_{i=1}^{6} Z_i/\sqrt{D_i}}{\sum_{i=1}^{6} 1/\sqrt{D_i}}}{2}$$

where Z'_{jk} is the desired interpolated value

Z_n is the nearest data value

Z_i are the six nearest data values

D_i are the corresponding distances from Z_i to Z'_{jk}.

c) Subroutine PRTCON4

This routine is also derived from a MAD language program obtained from the Department of Geography, University of Michigan, Ann Arbor. The program accepts a matrix of elevation values. These are assumed to form a square lattice (i.e. the spacing in the X-direction between columns equals the spacing in the Y-direction between rows).

Figure 3 is a flowchart of this program. Map scale is defined by specifying the width of the desired map in inches. The maximum allowed width is 12.7 inches. The routine computes the maximum number of print positions it can assign to each grid across the page, and the number of lines of type per grid down the page. This is accomplished by computing the following:

COL = WIDTH * 10.0 + 2.0

where COL is an integer number and equals the number of characters allowable since there are ten characters/inch.

PS = (COL - COLS)/(COLS-1)

where COLS = number of columns in matrix.

PS now is the number of characters between columns (see Figure 4). The final map width will thus be COLMAX = PS* (COLS-1) + COLS. It will never be greater than the requested size. The number of characters per grid is thus

XSTOP = PS + 1

the number of rows per grid (at 6 lines of type per inch) is thus

YSTOP = ((PS+1)*6+5)/10

All the above calculations are done in integer arithmetic.

Since the number of characters per inch (ten) is not equal to the number of lines per inch (six), distortions of the map result except at scales

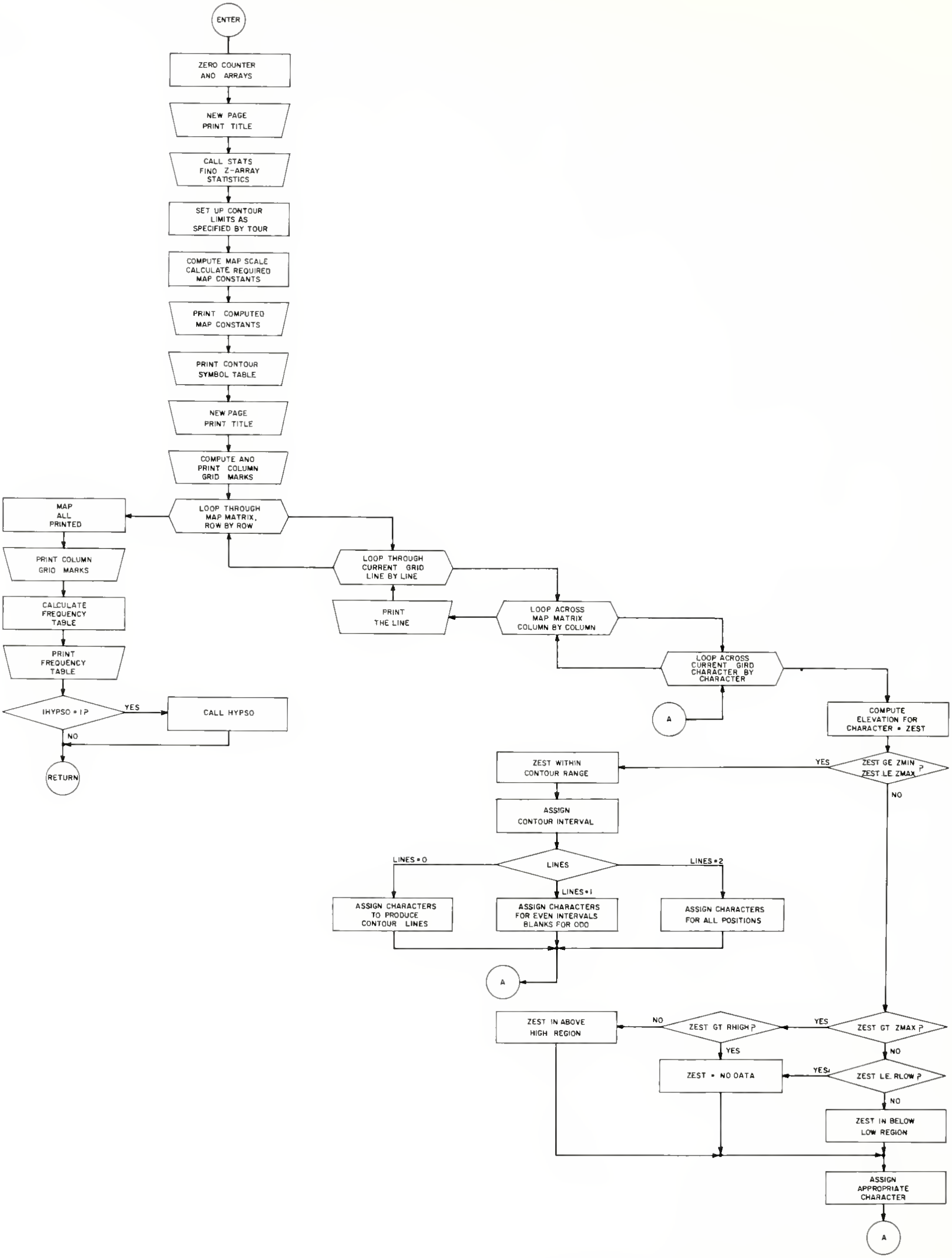
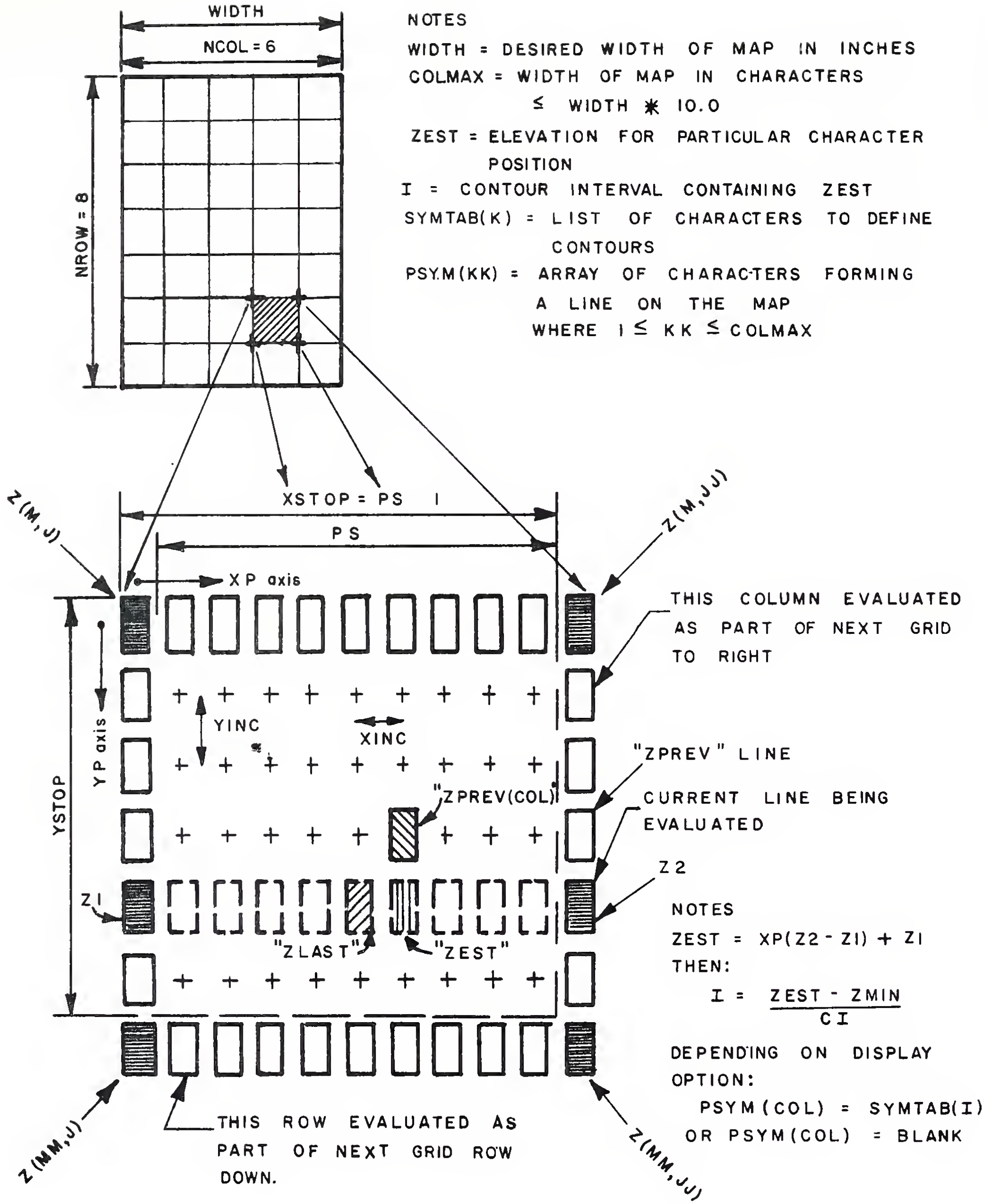

ENTER
ZERO COUNTER AND ARRAYS
NEW PAGE PRINT TITLE
CALL STATS FIND Z-ARRAY STATISTICS
SET UP CONTOUR LIMITS AS SPECIFIED BY TOUR
COMPUTE MAP SCALE CALCULATE REQUIRED MAP CONSTANTS
PRINT COMPUTED MAP CONSTANTS
PRINT CONTOUR SYMBOL TABLE
NEW PAGE PRINT TITLE
COMPUTE AND PRINT COLUMN GRID MARKS
LOOP THROUGH MAP MATRIX, ROW BY ROW
MAP ALL PRINTED
PRINT COLUMN GRID MARKS
CALCULATE FREQUENCY TABLE
PRINT FREQUENCY TABLE
IHYPSO = 1?
YES
CALL HYPSO
NO
RETURN
LOOP THROUGH CURRENT GRID LINE BY LINE
PRINT THE LINE
LOOP ACROSS MAP MATRIX COLUMN BY COLUMN
LOOP ACROSS CURRENT GIRD CHARACTER BY CHARACTER
A
COMPUTE ELEVATION FOR CHARACTER = ZEST
ZEST GE ZMIN ZEST LE ZMAX ?
YES
NO
ZEST WITHIN CONTOUR RANGE
ASSIGN CONTOUR INTERVAL
LINES
LINES = 0
LINES = 1
LINES = 2
ASSIGN CHARACTERS TO PRODUCE CONTOUR LINES
ASSIGN CHARACTERS FOR EVEN INTERVALS BLANKS FOR ODD
ASSIGN CHARACTERS FOR ALL POSITIONS
A
ZEST IN ABOVE HIGH REGION
NO
ZEST GT RHIGH ?
YES
ZEST GT ZMAX ?
YES
NO
ZEST = NO DATA
YES
ZEST LE RLOW ?
NO
ZEST IN BELOW LOW REGION
ASSIGN APPROPRIATE CHARACTER
A

FIGURE 3. FLOWCHART FOR SUBROUTINE PRTCON4.



NOTES

WIDTH = DESIRED WIDTH OF MAP IN INCHES

COLMAX = WIDTH OF MAP IN CHARACTERS $\leq$ WIDTH $*$ 10.0

ZEST = ELEVATION FOR PARTICULAR CHARACTER POSITION

I = CONTOUR INTERVAL CONTAINING ZEST

SYMTAB(K) = LIST OF CHARACTERS TO DEFINE CONTOURS

PSYM(KK) = ARRAY OF CHARACTERS FORMING A LINE ON THE MAP WHERE $1 \leq KK \leq COLMAX$

NOTES

ZEST = XP(Z2 - Z1) + Z1

THEN:

$$I = \frac{ZEST - ZMIN}{CI}$$

DEPENDING ON DISPLAY OPTION:

PSYM(COL) = SYMTAB(I)

OR PSYM(COL) = BLANK

FIGURE 4. PARAMETERS USED IN DEVELOPING A PRINTER MAP

where the grid spacings are some multiple of one half inch. Table 1 shows the distortions that will occur for all scales from a 0.2 inch grid (the smallest allowed) up to a one inch grid.

The actual map is computed and printed line by line, to save storage requirements. A line of blanks and plus signs is first generated (SYM) to define the column spacing along the top of the map.

The routine computes the estimated elevation, ZEST, at each character position by linear interpolation within the lattice. This is accomplished within four rested DO-Loops, as follows

(1) Loop through map matrix row by row,
(2) Loop through current grid printer line by printer line,
(3) Loop across map matrix column by column, within this
(4) Loop across current grid character by character.

Figure 4 shows the parameters used within the routine.

Once the value of ZEST has been obtained the routine merely has to assign an appropriate character to the print position according to the contour and display options specified (see below) and then move on to the next position.

By successively estimating elevations over an entire surface for a series of elemental areas (a character), the routine is performing numerical integration of the surface. For example by subtracting the ZEST values from a base level and summing the differences, a measure of volume between the surface and a base elevation could be computed. This is not presently done. However, the routine does keep track of the number of characters assigned to each contour level as well as the total number of characters within the area being contoured. A frequency table showing the percent area within each contour interval is readily produced. These data are further analyzed by Subroutine HYPSO.

TABLE 1

MAP DISTORTIONS PRODUCED ON COMPUTER

PS	XSTOP	YSTOP	XGRID	YGRID	% Elongation
1	2	1	0.20	0.167	-16.7%
2	3	2	0.30	0.333	+11.1%
3	4	2	0.40	0.333	-16.7%
4	5	3	0.50	0.50	0%
5	6	4	0.60	0.667	+11.1%
6	7	4	0.70	0.667	- 4.7%
7	8	5	0.80	0.833	+ 4.7%
8	9	5	0.90	0.833	- 7.4%
9	10	6	1.00	1.000	0%

Subroutine PRTCON4 includes many options allowing for various types of contour intervals and various types of displays.

i) Contour Options:

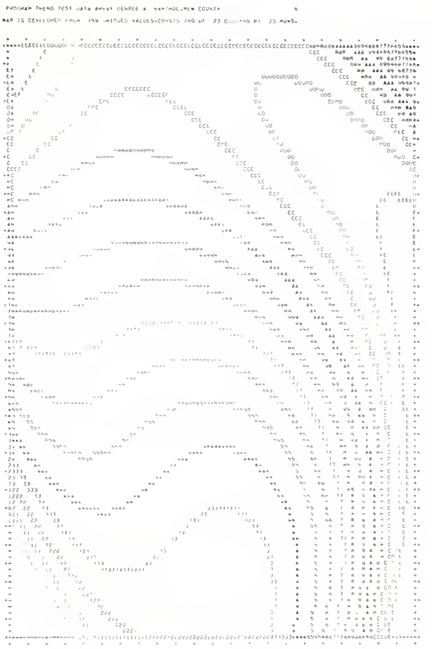
The number of contour intervals can be specified. The maximum number allowed is 19; the default option is 5. The contour intervals can be regularly spaced or they can be irregular. Irregularly spaced contours are useful if the data are mostly within a fairly narrow range, but there is one very high peak or deep hole. The contours can be specified so that they are close together in the common data range and widely spaced around the peak or hole. Regularly-spaced contours can be fitted within a specified range of elevations, or the range can be computed by the subroutine to conform to the total range of the data. Statistical contours, with an interval of one-half standard deviation and ranging from minus-three to plus-three standard deviations may also be requested.

ii) Display Options:

The routine can display any type of contours in any one of three ways. A series of contour lines may be printed in which the map area is blank except for strings of characters showing the location of contour lines. A series of contour bands may be requested. In this case the map will be composed of alternating blank and printed intervals since all even characters (0, 2, 4, etc) are printed while the odd characters (1, 3, 5, etc) are left blank. Finally, all print positions may be requested in which all the characters are printed without any blanks. Figure 5 shows an example of the three displays produced for a single area.

iii) Contouring Irregular Areas:

While the routine requires rectangular elevation matrices, irregular areas can be defined by setting all lattice points falling outside the desired



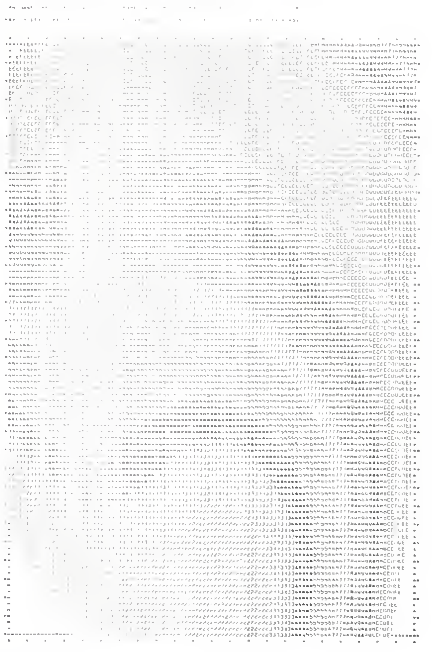


FIGURE 5. MAPS SHOWING THE THREE PRTCON4 DISPLAY OPTIONS.

area to arbitrarily very high or very low values. These points must lie at least one data range above the highest point or one data range below the lowest point. They will then be classified as "no data". Figure 6 shows the ranges as defined within Subroutine PRTCON4. The frequency table for irregular areas shows the percent area of the irregular area falling within each contour interval. Figure 7 shows the contouring of a drainage basin by PRTCON4.

d) Subroutine HYPSO

Figure 8 shows the hypsometric curve produced on the printer by Subroutine HYPSO. Hypsometric analysis is used be geomorphologists to measure the current stage in the erosion cycle for any drainage basin being analyzed (5, 8). The analysis is concerned with the relationship between altitude and areal extent. The hypsometric curve is merely a plot of relative altitude (on the vertical axis) versus relative area (on the horizontal axis). The relative altitude is computed as:

$$\text{Rel. Alt.} = (\text{Alt.} - A_o)/(A_1 - A_o) = h/H$$

where Rel. Alt. = relative altitude

Alt. = measured altitude

A_o = altitude of the lowest point in the basin

A_1 = altitude of the highest point in the basin

Thus the value of relative altitude ranges from zero (for lowest point) to one (for highest point).

The relative area is computed as:

$$\text{Rel. Area} = a/A.$$

where Rel. Area = relative area

a = the projected horizontal area of the region containing all the land lying above the corresponding altitude within the basin

A = the projected horizontal area of the entire basin.

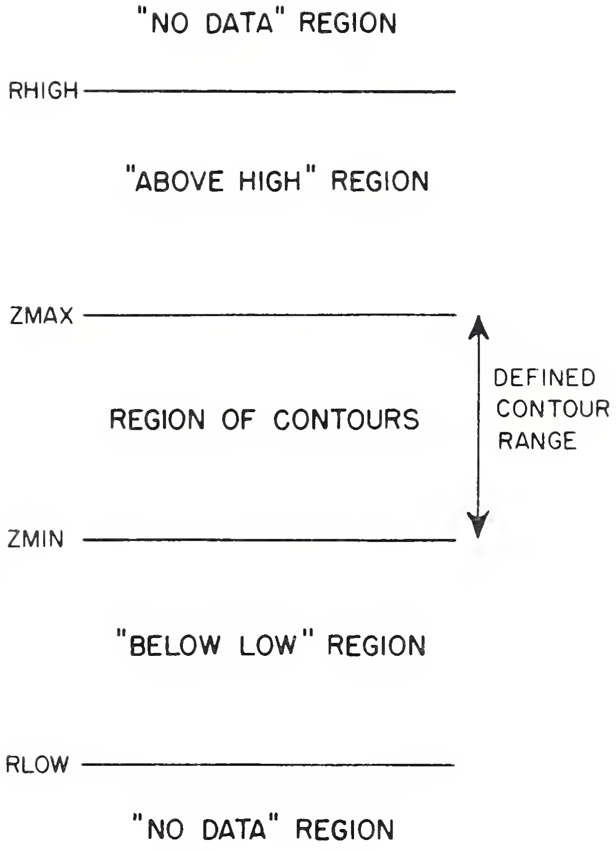
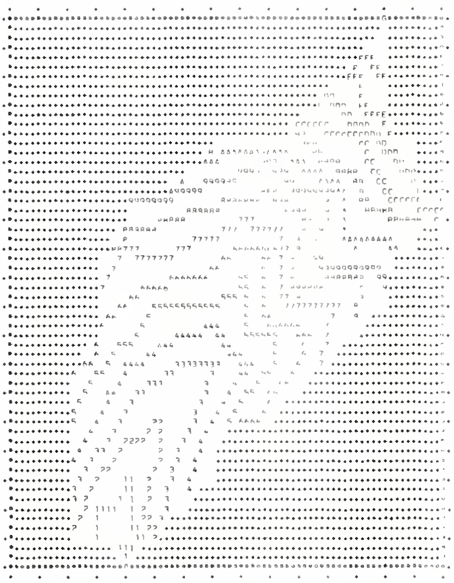


FIGURE 6. DEFINITION OF CONTOUR RANGE SPECIFICATIONS UTILIZED BY PRTCON4 .

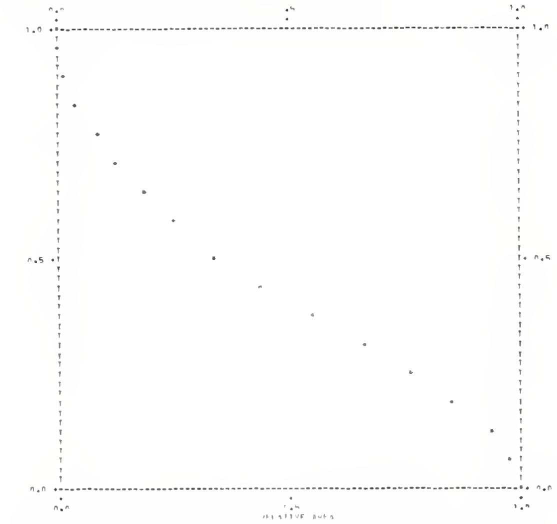
```
DRAINAGE BASIN, VERDUGO HILLS, CALIFORNIA.
MAP IS DEVELOPED FROM 320 GRIDDED VALUES,CONSISTING OF 16 COLUMNS BY 20 ROWS.
```



```
FREQUENCY TABLE
             INTERVAL                    UNITS     PERCENTAGE    CUMULATIVE
                  NO DATA                 2571
                BELOW LOW                    0       0.0000        0.0000
  1080.0000   TO     1130.0000              36       1.8529        1.8529
  1130.0000   TO     1180.0000              89       4.5777        6.4305
  1180.0000   TO     1230.0000             148       7.6246       14.0596
  1230.0000   TO     1280.0000             168       8.6619       22.7249
  1280.0000   TO     1330.0000             196      10.1362       32.8610
  1330.0000   TO     1380.0000             199      10.2907       43.1654
  1380.0000   TO     1430.0000             196      10.5722       53.7339
  1430.0000   TO     1480.0000             179       9.7566       63.4977
  1480.0000   TO     1530.0000             162       8.3424       71.8401
  1530.0000   TO     1580.0000             129       6.6520       78.4921
  1580.0000   TO     1630.0000             117       6.0311       84.5232
  1630.0000   TO     1680.0000              80       4.1327       88.6559
  1680.0000   TO     1730.0000              76       3.9287       92.5846
  1730.0000   TO     1780.0000              59       3.0376       95.6223
  1780.0000   TO     1830.0000              26       1.3269       96.9492
  1830.0000   TO     1880.0000              15        .7620       97.7112
  1880.0000   OR   OVER                     44       2.2888      100.0000
                 TOTAL                    1943     100.0000      100.0000
```

FIGURE 7. MAP OF DRAINAGE BASIN PRODUCED BY PRTCON4.

```
HYPSOMETRIC CURVE FOR DRAINAGE BASIN, VERDUGO HILLS, CALIFORNIA.
REL. HT.
```



```
CALCULATED VALUES OF HYPSOMETRIC CURVE COORDINATES

    POINT NUMBER      A-AXIS          H-AXIS

          1           1.0000          0.0000
          2            .9810           .0625
          3            .9342           .1250
          4            .8561           .1875
          5            .7474           .2500
          6            .6437           .3125
          7            .5583           .3750
          8            .4501           .4375
          9            .3503           .5000
         10            .2644           .5625
         11            .1944           .6250
         12            .1350           .6875
         13            .0937           .7500
         14            .0524           .8125
         15            .0234           .8750
         16            .0078           .9375
```

```
THE HYPSOMETRIC INTEGRAL FOR THE ABOVE CURVE ( THE AREA BELOW THE CURVE ) IS .42[illegible]
```

FIGURE 8. HYPSOMETRIC CURVE PRODUCED BY HYPSO.

Figure 9 shows these geometric relationships. It should be noted that the area below the curve, called the hypsometric integral, is a measure of the volume below the present surface relative to the total volume of the solid formed by the basin outline and horizontal planes passing through the highest and lowest points.

e) Program CONTUR

Program CONTUR is a modified version of a FORTRAN II program originally developed by F. J. Rens at the University of Michigan, Ann Arbor.

The main program (CONTUR) utilizes subroutines SCAN, TRACE, CALC, and DRAFT as well as the CALCOMP routine PLOT (with entry points PLOTS, SYMBOL, NUMBER, FACTOR, WHERE, and LINE). A dummy subroutine PROJ is included so that new options can be added easily. As shown in Figure 1 Subroutines SCAN, TRACE and CALC form one sequence, while DRAFT works more independently. The first three routines are concerned with the location of the contour line coordinates. Subroutine DRAFT issues the actual plot commands in conjunction with the CALCOMP routines.

PROGRAM OPERATING CHARACTERISTICS

a) Program MAPPER

Program MAPPER will compile, load, and execute about 50K (octal) central memory locations without Subroutine GRID (i.e. when regular data is being contoured). When GRID is needed almost 70K locations are required. Running times vary depending on the type of data (gridded or irregular) and the size of the grid and the original data when gridding is attempted. With regular (gridded) data an allowance of 2.5-3 seconds per map plus a 3 second compilation time will be adequate. When girdding is required, times will range from just under 20 seconds for 30 observations being interpolated onto a 23 x 33 grid to over 3 minutes for 1000 observations onto a 25 x 35

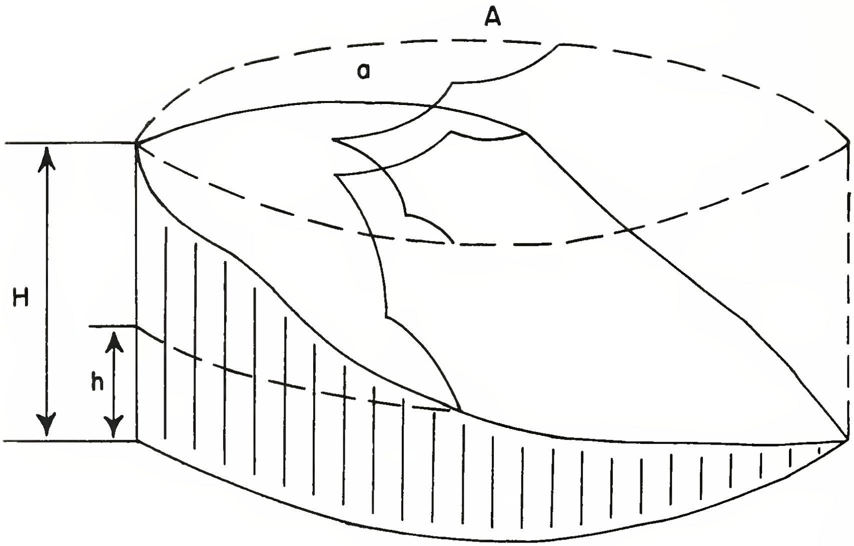


FIGURE 9. GEOMETRIC RELATIONSHIPS USED IN HYPSOMETRIC ANALYSIS.

grid. Figures 10 and 11 show typical deck setups for gridded data from either cards or tape. Irregular data deck setups are similar.

b) Program CONTUR

Program CONTUR will compile load, and execute in 60K (octal) central memory locations. Execution requires about 40K locations.

Running times vary with the size of the data matrix and the number of contour lines within a map. However for commonly encountered maps around 30 seconds is generally adequate. Figure 12 shows a typical output from Program CONTUR.

PROGRAM LISTINGS AND DOCUMENTATION

The following pages contain listings of the various routines in order. All are written in basic FORTRAN IV. Each routine is documented through the use of appropriate comment cards at the beginning and throughout the program.

Each program has been analyzed by Program TIDY, available as a library program at Purdue, which resequences all statement numbers, removes extraneous numbers, and generally makes the program neater. For this reason the statement numbers in each routine increase progressively in increments of five, and all FORMATS (if any) are collected at the end. The cards are each given a sequence number which appears at the far right.

a) The Use of FORSTAT Data

Each routine was next analyzed by another program, FORSTAT. This checks the syntax of source (FORTRAN) programs and produces cross-reference listings of all variables and statement numbers found within the routine. The cross-reference listings utilize a series of "FORSTAT Numbers" which are found at the far left of the listing. A vertical ink margin line has been added to separate these numbers from the rest of the listing. The cross-reference listings are found at the end of each routine.

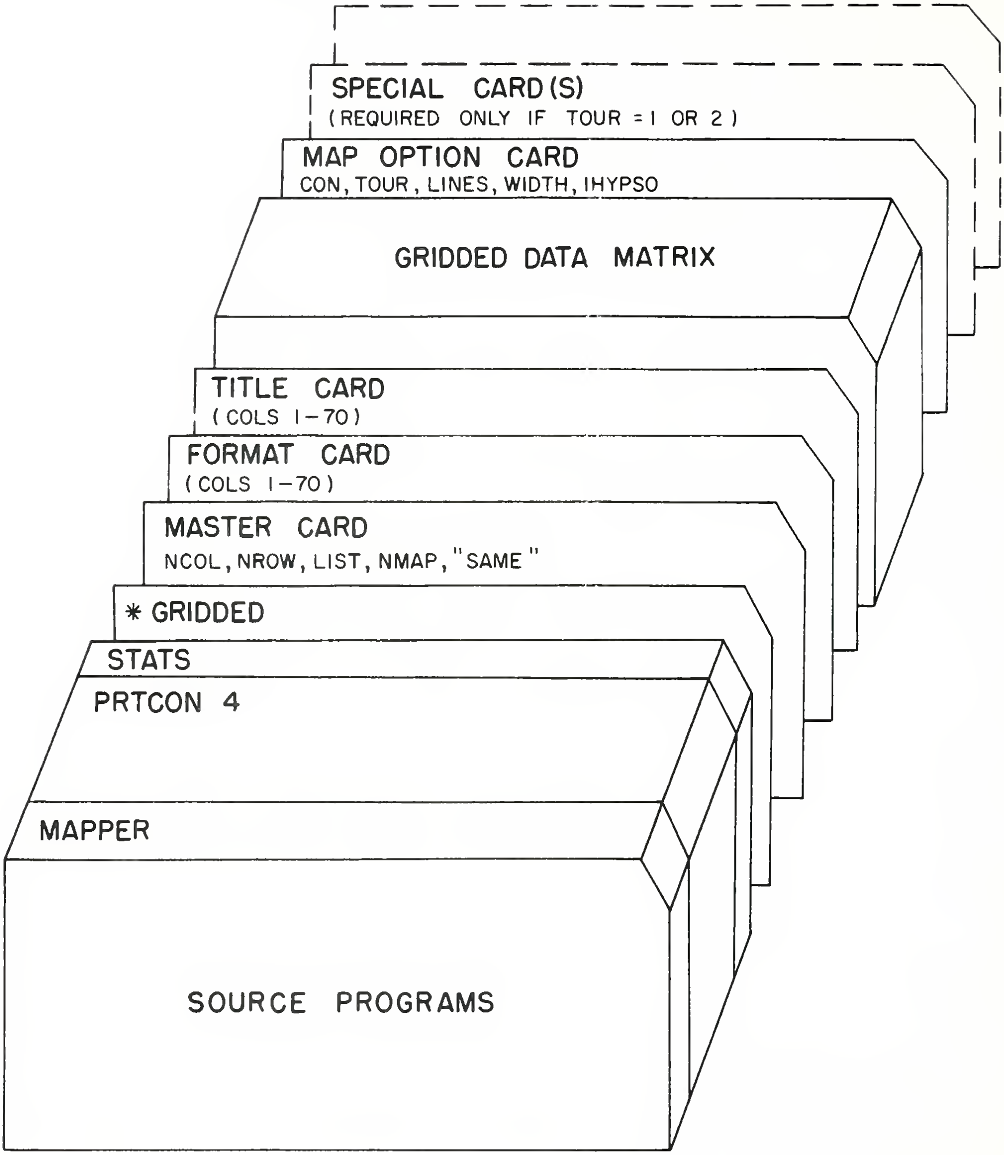


FIGURE 10. TYPICAL CARD DECK SETUP FOR ONE ANALYSIS USING CARD DATA

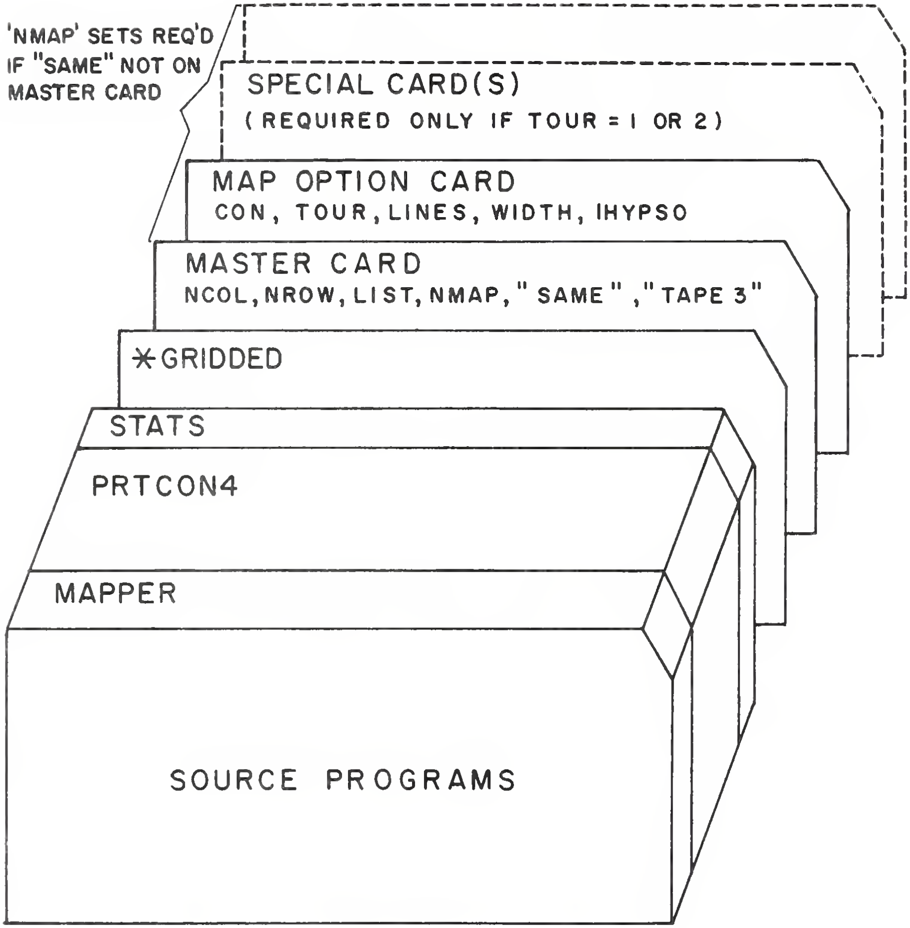


FIGURE 11. TYPICAL CARD DECK SETUP FOR ONE ANALYSIS USING DATA STORED ON TAPE3.

4TH DEGREE TREND SURFACE.APRIL 1967

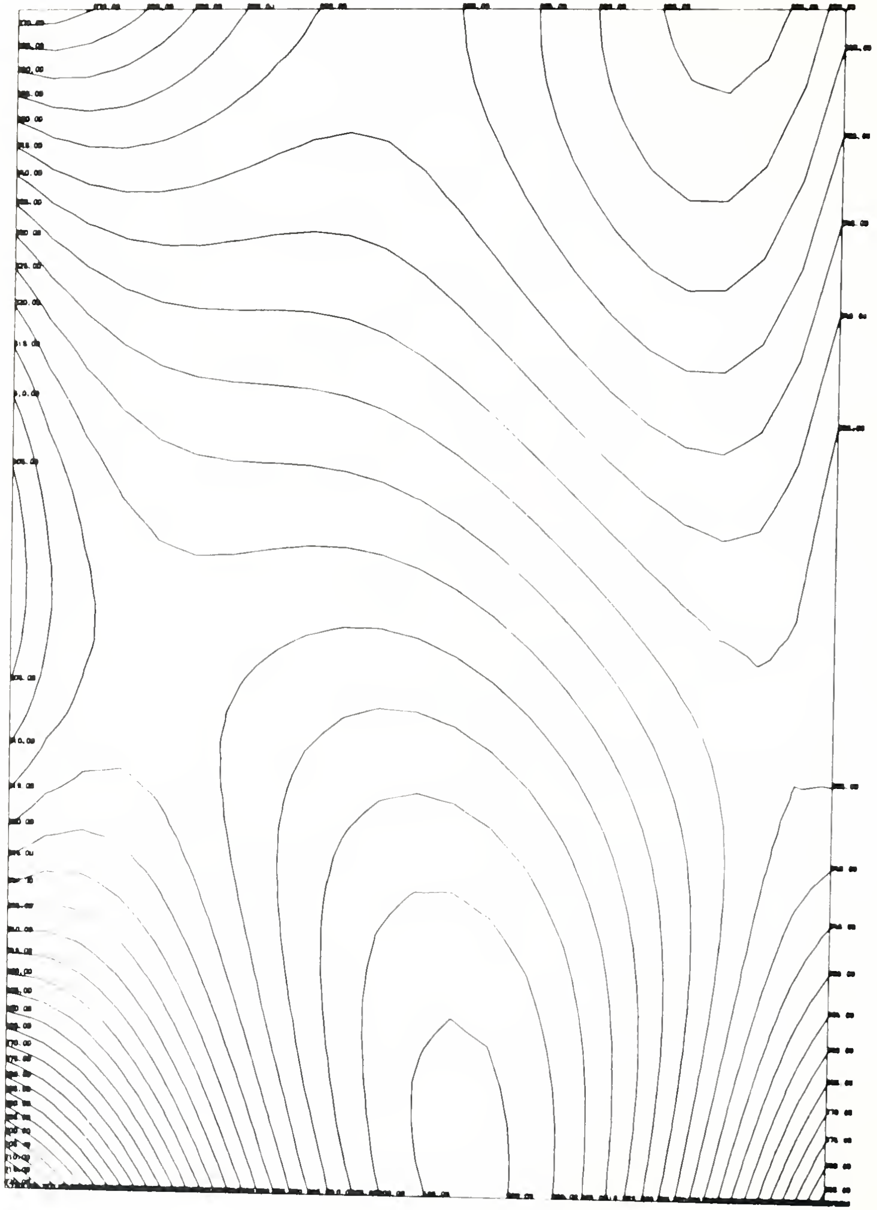


FIGURE 12. SAMPLE OUTPUT - PROGRAM CONTUR.

All symbols defined in the routine are listed alphabetically and are identified according to type, definition and references (where referenced).

The following symbols are utilized in the cross-reference listings:

Types I = INTEGER
R = REAL
D = DOUBLE PRECISION
C = COMPLEX
L = LOGICAL
N = NAME LIST
ASF = ARITHMETIC STATEMENT FUNCTION

Definition C = COMMON
D = DIMENSION
E = EQUIVALENCE

All other terms are believed self-explanatory. These cross-reference listings will be most useful should any reader desire to make changes to these routines.

b) LISTING OF PROGRAM MAPPER

```
      PROGRAM MAPPER(INPUT,OUTPUT,PUNCH,TAPE1,TAPE2,TAPE3,TAPE5=INPUT,TA
     1PE6=OUTPUT)
C     ------------------------------------------------------------------
C                             PROGRAM  MAPPER
C     ------------------------------------------------------------------
C
C     PURPOSE --
C          TO PREPARE GRIDDED OR IRREGULARCY SPACED THREE-DIMENSIONAL DATA
C     SUPPLIED FROM CARDS OR TAPE FOR THE PRODUCTION OF CONTOUR MAPS ON
C     THE PRINTER BY SUBROUTINE PRTCON4 .
C
C     ------------------------------------------------------------------
C                    THE GCARS SYSTEM
C                    PURDUE UNIVERSITY
C
C                                                 A. KEITH TURNER,
C                                                 CIVIL ENGINEERING,
C                                                 JUNE 1969.
C     ------------------------------------------------------------------
C
C                             GENERAL INFORMATION
C                             -------------------
C          THIS PROGRAM CONTAINS THREE SECTIONS.ONE IS USED WHEN IRREGULAR
C     DATA IS SUPPLIED,ANOTHER WHEN GRIDDED DATA IS SUPPLIED, AND THE
C     THIRD CALLS SUBROUTINE PRTCON4 TO PRODUCE THE MAPS.
C
C          IRREGULAR DATA MAY BE SUPPLIED FROM EITHER CARDS OR TAPE(TAPE2)
C     IT IS GRIDDED BY SUBROUTINE GRID ACCORDING TO SPECIFICATIONS SUPPLI-
C     ED BY THE USER. SINCE SUBROUTINE GRID CANNOT HANDLE MORE THAN 1000
C     OBSERVATIONS AT A TIME, PROGRAM MAPPER GEOGRAPHICALLY *PRE-SORTS*
C     LARGER ARRAYS INTO SUBSET (REPRESENTING SUBAREAS) ,EACH CONTAINING
C     LESS THAN 1000 POINTS. THE COMPUTED GRIDDED VALUES MAY BE PLACED
C     ON A TAPE (TAPE3) OR PUNCHED.
C
C          GRIDDED DATA MAY BE SUPPLIED FROM EITHER CARDS OR TAPE(TAPE3).
C     SINCE THIS DATA ARE ALREADY IN A SUITABLE FORM FOR SUBROUTINE
C     PRTCON4 , NO FURTHER MODIFICATIONS ARE REQUIRED.
C
C     ------------------------------------------------------------------
C
C     TAPE REQUIREMENTS --
C     THE PROGRAM UTILIZES THREE TAPE FILES IN ADDITION TO THE
C     NORMAL INPUT, OUTPUT, AND PUNCH FILES. THE NUMBER REQUIRED DEPENDS
C     ON THE OPTIONS REQUESTED. THE TAPES ARE -
C        A)  TAPE1 - A SCRATCH TAPE USED TO STORE ORIGINAL SUPPLIED LARGE
C                      IRREGULAR DATA ARRAYS DURING PRE-SORTING.
C        B)  TAPE2 - INPUT TAPE FOR IRREGULAR DATA.(USE OPTIONAL)
C        C)  TAPE3 - INPUT TAPE FOR GRIDDED DATA) (USE OPTIONAL)
C                  - OR - OUTPUT TAPE FOR CALCULATED GRIDDED VALUES FROM
C                      INTERPOLATION OF IRREGULAR DATA. (USE OPTIONAL)
C
C     ------------------------------------------------------------------
C     DESCRIPTION OF CONTROL CARDS --
C
C     1) DATA IDENTIFICATION CARD -
C          THE FIRST CONTROL CARD IDENTIFIES THE TYPE OF DATA BEING
C          SUPPLIED BY EITHER OF TWO CODE WORDS IN COLS 1-10 .
C          *IRREGULAR - INDICATES IRREGULARLY SPACED DATA .
C          *GRIDDED    - INDICATES GRIDDED DATA .
C
C                        -------------------------
C     A) CARDS FOR IRREGULAR DATA
C     --------------------------
C
C     A1) MASTER OPTION CARD -
C          NTAPE  (COLS  1- 5)-THE WORD *TAPE2* IN THESE COLUMNS INDICATES
C                              THAT THE DATA IS TO BE SUPPLIED FROM TAPE.
C          KONTOR (COLS  6-10)-THE WORD *SAME* IN THESE COLUMNS INDICATES
C                              THAT THE REQUESTED MAPS ARE TO BE IDENTICAL
C          IOUT   (COLS 11-15)-THE WORD *TAPE3* IN THESE COLUMNS INDICATES
C                              THAT THE COMPUTED GRID VALUES ARE TO BE
C                              PLACED ON TAPE .
C          NAREA  (COLS 16-20)-NUMBER OF SUBAREAS DATA IS TO BE PRESORTED
C                              INTO. THIS MUST BE AT LEAST ONE EVEN IF NO
C                              SUBDIVISION IS REQUIRED.
C          NOBS   (COLS 21-25)-NUMBER OF OBSERVATIONS BEING SUPPLIED
C          NPT    (COLS 26-30)-NUMBER OF OBSERVATIONS RECORDED/CARD.
C
C     THE FOLLOWING CARDS REQUIRED ONLY IF DATA SUPPLIED FUM CARDS -
C     ----------------------------------------------------------
```

```
C
C    A2) FORMAT CARD -
C         FORM   (COLS  1-70)-FORMAT FOR DATA CARDS.
C
C    A3) AREA HEADER CARD -
C         FACTOR (COLS  1-30)-ALPHANUMERIC IDENTIFICATION OF FACTOR.
C         AREA   (COLS 41-70)-ALPHANUMERIC IDENTIFICATION OF AREA.
C         ITYPE  (  COLS 76 )-IF DATA IS TOPOGRAPHIC RESIDUALS,ITYPE=1 .
C                             IF DATA MEASURES COSTS , ITYPE=2 .
C                             IF DATA MEASURES BENEFITS,ITYPE=3 .
C
C    A4) DATA CARDS --
C
C    THE FOLLOWING CARDS ARE USED TO DEFINE THE SUBAREAS -
C    ------------------------------------------------
C    AT LEAST ONE SET IS ALWAYS REQUIRED , EVEN WHEN NO SUBDIVISION IS
C    NECESSARY . THE OVERALL AREA MUST AT LEAST BE DEFINED ON THESE CARDS
C
C    A5) SUBAREA TITLE CARD -
C         TITL   (COLS  1-70)-ALPHANUMERIC IDENTIFYING TITLE.
C
C    A6) SUBAREA LIMIT SPECIFICATION CARD -
C         XMAX   (COLS  1-10)-MAXIMUM X-COORDINATE OF SUBAREA.
C         XMIN   (COLS 11-20)-MINIMUM X-COORDINATE OF SUBAREA.
C         YMAX   (COLS 21-30)-MAXIMUM Y-COORDINATE OF SUBAREA.
C         YMIN   (COLS 31-40)-MINIMUM Y-COORDINATE OF SUBAREA.
C
C    A7) GRID SPECIFICATION CARD -
C         NROW   (COLS  1-3 )-NUMBER OF ROWS IN GRID.
C         NCOL   (COLS  4-6 )-NUMBER OF COLUMNS IN GRID.
C         GSIZE  (COLS  7-10)-SIZE OF GRID IN X-Y INPUT DATA UNITS.
C         BND    ( COL   11  )-IF BND=0,GRID BOUNDARIES CALCULATED FROM
C                             DATA ACCORDING TO ALGORITHM.
C                             IF BND=1,GRID BOUNDARIES=XMAX,XMIN,YMAX,
C                             YMIN AS SPECIFIED PREVIOUSLY.
C         ILIST  (  COL 12  )-IF ILIST=1,INPUT (IRREGULAR) DATA LISTED.
C                             IF ILIST=2,OUTPUT(GRIDDED) DATA LISTED.
C                             IF ILIST=3,BOTH INPUT AND OUTPUT DATA ARE
C                             LISTED.
C         IPUN   (  COL 13  )-IF IPUN=1,GRID VALUES ARE PUNCHED.
C         NMAP   (COLS 14-15)-NUMBER OF MAP COPIES TO BE PRODUCED FOR
C                             THIS SUBAREA.
C
C       COMPLETE CONTROL CARD PACKAGE WITH CARDS IN PART C.
C
C                        -------------------------
C
C    B) CARDS FOR GRIDDED DATA --
C    -------------------------
C    B1) MASTER OPTION CARD -
C         LIST   (  COL 1    )-IF LIST=1, INPUT DATA ARRAY IS LISTED.
C         NMAP   (COLS  2-3 )-NUMBER OF MAP COPIES TO BE PRODUCED FOR
C                             THIS DATA SET.
C         KONTUR (COLS  6-10)-THE WORD ≠SAME≠ IN THESE COLUMNS INDICATES
C                             THAT THE REQUESTED MAPS ARE TO BE IDENTICAL
C         MATRIX (COLS 11-15)-THE WORD ≠TAPE3≠ IN THESE COLUMNS INDICATES
C                             THAT THE DATA IS TO BE SUPPLIED FROM TAPE.
C
C    THE FOLLOWING CARDS REQUIRED ONLY IF DATA SUPPLIED FOM CARDS -
C    ------------------------------------------------------------
C
C    B2) FORMAT CARD -
C         FORM   (COLS  1-70)-FORMAT FOR DATA CARDS.
C
C    B3) DATA SET HEADER CARD -
C         TITL   (COLS  1-70)-ALPHANUMERIC IDENTIFYING TITLE.
C         NCOL   (COLS 71-73)-NUMBER OF COLUMNS IN THE ARRAY.
C         NROW   (COLS 74-76)-NUMBER OF ROWS IN THE ARRAY.
C         ITYPE  (  COLS 78 )-IF DATA IS TOPOGRAPHIC RESIDUALS,ITYPE=1 .
C                             IF DATA MEASURES COSTS , ITYPE=2 .
C                             IF DATA MEASURES BENEFITS,ITYPE=3 .
C
C       COMPLETE CONTROL CARD PACKAGE WITH CARDS IN PART C.
C
C                        -------------------------
```

```
C                                                                         A 312
C    ( )  MAP SPECIFICATION CARDS --                                      A 314
C    ---------------------------                                          A 316
C    NMAP SETS OF THESE REQUIRED UNLESS *SAME* ENTERED ON THE APPROPRIATE A 318
C    COLUMNS OF CONTROL CARDS A1 OR B1 .                                  A 320
C                                                                         A 322
C    (1) MAP SPECIFICATION CARD -                                         A 324
C         CON(COL1-2)-THE NUMBER OF CONTOUR INTERVALS (MAXIMUM = 19).     A 326
C                    ( CON = DATA RANGE / DESIRED CONTOUR INTERVAL ).     A 328
C         IOUR(COL3)- IF IOUR = 0, PROGRAM USES MAXIMUM AND MINIMUM FROM  A 330
C                    DATA FOR UPPER AND LOWER CONTOUR LIMITS.             A 332
C                    IF IOUR = 1, DESIRED TOP AND BOTTOM CONTOURS READ    A 334
C                    IN FROM SPECIAL PROGRAM CARD (SEE BELOW).            A 336
C                    IF IOUR = 2, VARIABLE CONTOURS READ IN (LOW TO       A 338
C                    HIGH).  IN THIS CASE SET CON EQUAL TO THE NUMBER     A 340
C                    OF VALUES TO BE READ IN.                             A 342
C                    IF IOUR = 3, CONTOUR INTERVAL BECOMES 1/2 STANDARD   A 344
C                    DEVIATION ( MAX = +3 SIGMA, MIN = -3 SIGMA ).        A 346
C         LINES(COL4) IF LINES = 0, CONTOUR LINES ARE PRINTED.            A 348
C                    IF LINES = 1, ALTERNATE (EVEN VALUED) CONTOUR BANDS  A 350
C                    ARE PRINTED                                          A 352
C                    IF LINES = 2, ALL BANDS PRINTED (ALL PRINT POSNS).   A 354
C         WIDTH(COL 5-8)- WIDTH IS MAP WIDTH IN INCHES. IF GREATER THAN   A 356
C                    12.7 OR BLANK, SET TO 10.0                           A 358
C         IHYPSO(COL 10)-IF IHYPSO = 1,SUBROUTINE HYPSO CALLED.           A 360
C                                                                         A 362
C    (2) SPECIAL CARDS - REQUIRED ONLY WHEN IOUR= 1 OR 2 .                A 364
C         IF IOUR = 1                                                     A 366
C              ONE CARD CONTAINING-                                       A 368
C                   ZMIN (COLS  1-10)-MINIMUM CONTOUR ELEVATION.          A 370
C                   ZMAX (COLS 11-20)-MAXIMUM CONTOUR ELEVATION.          A 372
C         IF IOUR = 2                                                     A 374
C              ONE CARD CONTAINING-                                       A 376
C                   INCON (COLS 1-80)-FORMAT FOR FOLLOWING DATA CARDS.    A 378
C              PLUS ONE OR MORE CARDS CONTAINING-                         A 380
C                   A SERIES OF VALUES REPRESENTING THE HEIGHTS OF THE    A 382
C                   IRREGULARLY SPACED CONTOURS. THSE MUST BE ARRANGED    A 384
C                   FROM LOWEST TO HIGHEST IN ORDER.                      A 386
C                                                                         A 388
C                        -------------------------                        A 390
C                                                                         A 392
C    NOTE --                                                              A 394
C         THIS PROGRAM UTILIZES LABELLLED COMMON                          A 396
C                   /GDATA/                                               A 398
C                   /MAPS/                                                A 400
C                                                                         A 402
C    -----------------------------------------------------------------   A 404
C                                                                         A 406
C    REQUIRED SUBROUTINES -                                               A 408
C         GRID - ONLY WHEN IRREGULAR DATA SUPPLIED.                       A 410
C         PRTCON4                                                         A 412
C         STATS                                                           A 414
C                                                                         A 416
C    OPTIONAL SUBROUTINES -                                               A 418
C         HYPSO                                                           A 420
C                                                                         A 422
C    -----------------------------------------------------------------   A 424
      DIMENSION AREA(3), FACTOR(3)                                        A 426
      DIMENSION TITL(7), FORM(7), Z(50,50), ICODE(5), XT(1000), YT(1000)  A 428
     1, ZT(1000), X(1000), Y(1000), W(1000)                               A 430
      INTEGER CON,IOUR                                                    A 432
      INTEGER SYSIN,SYSOT,SDF1,SDF2,SDF3                                  A 434
      COMMON /GDATA/ KOUNT,X,Y,W,TITL,NROW,NCOL,ITYPE,GSIZE,IND,ILIST,IP  A 436
     1UN,KTAPE,XMAX,XMIN,YMAX,YMIN                                        A 438
      COMMON /MAPS/ CON,IOUR,LINES,WIDTH,IHYPSO,INCON(8),DRANG(25),ZMIN,  A 440
     1ZMAX                                                                A 442
      DATA SYSIN,SYSOT,SDF1,SDF2,SDF3/5,6,1,2,3/                          A 444
      DATA (ICODE(I),I=1,5)/5HSAME ,5HTAPE3,10H*IRREGULAR,10H*GRIDDED  ,  A 446
     15HTAPE2/                                                            A 448
      EQUIVALENCE (Z,XT), (Z(1001),YT), (Z(2001),ZT)                      A 450
      REWIND SDF3                                                         A 452
      REWIND SDF2                                                         A 454
    5 KTAPE=0                                                             A 456
      KODE=3                                                              A 458
      READ (SYSIN,225) ISWCH                                              A 460
```

```
C     --------------------------------------                              A 462
C     READ CARD IDENTIFYING TYPE OF DATA                                  A 464
C     --------------------------------------                              A 466
        IF (EOF,SYSIN) 175,10                                             A 468
10      IF (ISWCH.EQ.ICODE(3)) KODE=1                                     A 470
        IF (ISWCH.EQ.ICODE(4)) KODE=2                                     A 472
        GO TO (15,110,180), KODE                                          A 474
C     --------------------------------------                              A 476
C     IRREGULAR DATA SPECIFIED                                            A 478
C     --------------------------------------                              A 480
C     READ MASTER OPTION SPECIFICATION CARD                               A 482
C     --------------------------------------                              A 484
15      READ (SYSIN,230) NTAPE,KONTUR,IOUT,NAREA,NOBS,NPT                 A 486
        IF (IOUT.EQ.ICODE(2)) KTAPE=1                                     A 488
        IF (NTAPE.NE.ICODE(5)) GO TO 40                                   A 490
C     --------------------------------------                              A 492
C     INPUT DATA FROM TAPE2                                               A 494
C     READ LABEL AND DATA RECORDS FROM TAPE2                              A 496
C     AND PLACE DATA RECORDS ON TAPE1                                     A 498
C     --------------------------------------                              A 500
        READ (SOF2) FACTOR,AREA,ITYPE                                     A 502
        IF (NOBS.GT.1000) GO TO 20                                        A 504
        KNUM=1                                                            A 506
        KTR=NOBS                                                          A 508
        KISW=1                                                            A 510
        GO TO 25                                                          A 512
C                                                                         A 514
20      KNUM=NOBS/1000                                                    A 516
        JNUM=NOBS-KNUM*1000                                               A 518
        KTR=1000                                                          A 520
        KISW=0                                                            A 522
25      DO 35 K=1,KNUM                                                    A 524
30          READ (SOF2) (XT(I),YT(I),ZT(I),I=1,KTR)                       A 526
35      WRITE (SOF1) (XT(I),YT(I),ZT(I),I=1,KTR)                          A 528
        IF (KISW.EQ.1) GO TO 70                                           A 530
        KTR=JNUM                                                          A 532
        KISW=1                                                            A 534
        GO TO 30                                                          A 536
C                                                                         A 538
C     --------------------------------------                              A 540
C     DATA FROM CARDS                                                     A 542
C     READ FORMAT CARD THEN AREA HEADER CARD                              A 544
C     THEN READ DATA FROM CARDS AND PLACE ON TAPE1                        A 546
C     --------------------------------------                              A 548
40      READ (SYSIN,200) FORM                                             A 550
        READ (SYSIN,185) FACTOR,AREA,ITYPE                                A 552
        IF (NOBS.GT.1000) GO TO 45                                        A 554
        JNUM=NOBS                                                         A 556
        GO TO 60                                                          A 558
C                                                                         A 560
45      KNUM=NOBS/1000                                                    A 562
        JNUM=NOBS-KNUM*1000                                               A 564
        NSTEP=(1000./FLOAT(NPT))+.9                                       A 566
        DO 55 K=1,KNUM                                                    A 568
            IBEG=1                                                        A 570
            DO 50 N=1,NSTEP                                               A 572
                IEND=IBEG+NPT-1                                           A 574
                READ (SYSIN,FORM) (XT(I),YT(I),ZT(I),I=IBEG,IEND)         A 576
50          IBEG=IBEG+NPT                                                 A 578
55      WRITE (SOF1) (XT(I),YT(I),ZT(I),I=1,1000)                         A 580
60      NSTEP=(FLOAT(JNUM)/FLOAT(NPT))+.9                                 A 582
        IBEG=1                                                            A 584
        DO 65 N=1,NSTEP                                                   A 586
            IEND=IBEG+NPT-1                                               A 588
            READ (SYSIN,FORM) (XT(I),YT(I),ZT(I),I=IBEG,IEND)             A 590
65      IBEG=IBEG+NPT                                                     A 592
        WRITE (SOF1) (XT(I),YT(I),ZT(I),I=1,JNUM)                         A 594
C     --------------------------------------                              A 596
C     SUBDIVIDE DATA INTO SUBAREAS BY SEARCHING DATA ON TAPE1             A 598
C     --------------------------------------                              A 600
C     READ SUBAREA TITLE CARD,THEN SUBAREA LIMITS CARD,                   A 602
C     THEN GRID SPECIFICATION CARD.                                       A 604
C     EACH SUBAREA MUST HAVE NO MORE THAN 1000 OBSERVATIONS               A 606
```

```
C     ------------------------------------
70       DO 170 NN=1,NAREA
            MYSW=0
            KOUNT=1
            REWIND SDF1
            READ (SYSIN,200) TITL
            READ (SYSIN,235) XMAX,XMIN,YMAX,YMIN
            READ (SYSIN,240) NROW,NCOL,GSIZE,RND,ILIST,IPUN,NMAP
            IF (NOBS.GT.1000) GO TO 75
            KNUM=1
            KTR=NOBS
            KTSW=1
            GO TO 80
C
75          KNUM=NOBS/1000
            JNUM=NOBS-KNUM*1000
            KTR=1000
            KTSW=0
80          DO 95 K=1,KNUM
85             READ (SDF1) (XT(I),YT(I),ZT(I),I=1,KTR)
                  DO 90 I=1,KTR
                     IF (XT(I).LT.XMIN.OR.XT(I).GT.XMAX) GO TO 90
                     IF (YT(I).LT.YMIN.OR.YT(I).GT.YMAX) GO TO 90
                     X(KOUNT)=XT(I)
                     Y(KOUNT)=YT(I)
                     W(KOUNT)=ZT(I)
                     KOUNT=KOUNT+1
                     IF (KOUNT.GT.1000) GO TO 105
C     ------------------------------------
C     IF PREVIOUS STATEMENT IS TRUE,MORE THAN 1000 POINTS HAVE
C     BEEN FOUND IN THE CURRENT SUBAREA. ALL GRIDDING AND
C     CONTOURING ATTEMPTS ARE ABORTED FOR THIS AREA,
C     BUT MAP CONTROL CARDS ARE READ SO THAT CORRECT CONTROL
C     CARDS WILL BE FOUND BY SUBSEQUENT ANALYSES.
C     ------------------------------------
90                CONTINUE
95          CONTINUE
            IF (KTSW.EQ.1) GO TO 100
            KTR=JNUM
            KTSW=1
            GO TO 85
C
100         KOUNT=KOUNT-1
C     ------------------------------------
C     CALL SUBROUTINE GRID TO GRID THE DATA
C     ------------------------------------
            CALL GRID (Z,50,50)
            GO TO 135
C
105         MYSW=1
            WRITE (SYSOT,245) TITL
            GO TO 135
C
C     ------------------------------------
C     GRIDDED INPUT DATA SPECIFIED
C     ------------------------------------
C     READ MASTER OPTION SPECIFICATION CARD
C     ------------------------------------
110         READ (SYSIN,190) LIST,NMAP,KONTUR,MATRIX
            IF (EOF,SYSIN) 175,115
115         IF (NMAP.LT.1) NMAP=1
            IF (MATRIX.EQ.ICODE(2)) GO TO 125
C     ------------------------------------
C     CARD INPUT DATA SPECIFIED
C     ------------------------------------
C     READ FORMAT CARD, THEN TITLE CARD
C     THEN THE MATRIX ROW BY ROW
C     ------------------------------------
            READ (SYSIN,200) FORM
            READ (SYSIN,195) TITL,NROW,NCOL,ITYPE
            DO 120 I=1,NROW
120         READ (SYSIN,FORM) (Z(I,J),J=1,NCOL)
            GO TO 135
C
C     ------------------------------------
C     INPUT DATA ON TAPE3
C     ------------------------------------
C     READ IDENTIFICATION RECORD
C     THEN READ MATRIX ROW BY ROW
C     ------------------------------------
```

```
 125       READ (SDF3) (TITL(I),I=1,4),(TITL(I),I=5,7),NCOL,NROW,ITYPE
           DO 130 I=1,NROW
 130       READ (SDF3) (Z(I,J),J=1,NCOL)
 C     ------------------------------------
 C     PREPARE CONTOUR MAPS
 C     READ CONTOUR MAP CONTROLS
 C     IF *SAME* OPTION REQUESTED, ONLY ONE SET OF CONTROL CARDS IS READ
 C     ------------------------------------
 135       DO 165 N=1,NMAP
               IF (KONTUR.EQ.ICODE(1).AND.N.GT.1) GO TO 160
               READ (SYSIN,205) CON,IOUR,LINES,WIDTH,IHYPSO
               IF (IOUR.GT.2.OR.IOUR.LE.0) GO TO 150
               GO TO (140,145), IOUR
 140           READ (SYSIN,210) ZMIN,ZMAX
               GO TO 150
 C
 145           READ (SYSIN,200) INCON
               READ (SYSIN,INCON) (ORANG(I),I=1,CON)
 150           CONTINUE
 C     ------------------------------------
 C     IF LIST = 1,LIST INPUT DATA MATRIX
 C     ------------------------------------
               IF (N.GT.1.OR.LIST.NE.1) GO TO 160
               WRITE (SYSOT,215) TITL
               DO 155 I=1,NROW
 155           WRITE (SYSOT,220) (Z(I,J),J=1,NCOL)
 C     ------------------------------------
 C     CALL PRTCON4 TO PRODUCE CONTOUR MAPS
 C     NMAP SPECIFIES NUMBER OF MAPS TO BE PRODUCED FOR THIS DATA
 C     ------------------------------------
 160           CALL PRTCON4 (Z,TITL,NROW,NCOL,50,50)
 165       CONTINUE
 170   CONTINUE
       GO TO 5
 C
 175   REWIND SDF3
 180   CONTINUE
       STOP
 C
 185   FORMAT (3A10,10X,3A10,6X,I2)
 190   FORMAT (I1,I2,2X,2A5)
 195   FORMAT (/A10,2I3,I2)
 200   FORMAT (/A10)
 205   FORMAT (I2,2I1,F4.0,I2)
 210   FORMAT (2F10.0)
 215   FORMAT (1H1,55X,29H-----------------------------,/,56X,29HI           T
      1HE GCARS SYSTEM       I,/,56X,29HI PURDUE UNIVERSITY VERSION I,/,56X
      2,29H-----------------------------,///,45X,38HDEVELOP CONTOUR MAPS
      3FOR GRIDDED DATA.,///,25X,15HTHIS MAP SHOWS ,7A10,//,40X,36HIT IS
      4BASED ON THE FOLLOWING DATA --,///)
 220   FORMAT (1H0,12F10.3,/(1X,12F10.3))
 225   FORMAT (A10)
 230   FORMAT (3A5,3I5)
 235   FORMAT (4F10.0)
 240   FORMAT (2I3,F4.0,3I1,I2)
 245   FORMAT (1H1,42H***ERROR*** TOO MANY POINTS IN TEST AREA  ,/,12X,7A
      110,/,12X,25HGOING ON TO NEXT REQUEST.)
       END
```

c) FORSTAT CROSS-REFERENCE LISTING FOR PROGRAM MAPPER

```
 PROGRAM    MAPPER

  STATEMENT NUMBER   DEFINITION                                   REFERENCES

          5           13.                  129.
         10           17.                   16.
         15           20.                   19.
         20           29.                   24.
         25           33.                   28.
         30           34.                   39.
         35           35.                   33.
         40           40.                   22.
         45           45.                   42.
         50           53.                   50.
         55           54.                   48.
         60           55.                   44.
         65           60.                   57.
         70           62.                   36.
         75           74.                   69.
         80           78.                   73.
         85           79.                   93.
         90           88.                   80.    81.    82.
         95           89.                   78.
        100           94.                   90.
        105           97.                   87.
        110          100.                   19.
        115          102.                  101.
        120          107.                  106.
        125          109.                  103.
        130          111.                  110.
        135          112.                   96.    99.   108.
        140          117.                  116.
        145          119.                  116.
        150          121.                  115.  118.
        155          125.                  124.
        160          126.                  113.  122.
        165          127.                  112.
        170          128.                   62.
        175          130.                   16.  101.
        180          131.                   19.
        185          133.       FORMAT      41.
        190          134.       FORMAT     100.
        195          135.       FORMAT     105.
        200          136.       FORMAT      40.    66.   104.   119.
        205          137.       FORMAT     114.
        210          138.       FORMAT     117.
        215          139.       FORMAT     123.
        220          140.       FORMAT     125.
        225          141.       FORMAT      15.
        230          142.       FORMAT      20.
        235          143.       FORMAT      67.
        240          144.       FORMAT      68.
        245          145.       FORMAT      98.


 49 STATEMENT NUMBERS DEFINED

  4 MAXIMUM NUMBER OF REFERENCES

 59 TOTAL     NUMBER OF REFERENCES

1.2 AVERAGE   NUMBER OF REFERENCES
```

```
PROGRAM     MAPPER

 LABEL       TYPE       DEFINITION                                  REFERENCES

AREA         R             2.  D                   23.   41.
RNO          R             6.  C                   68.
CON          I             4.  C                    7.  114.  120.
ORANG        R             7.  CD                 120.
EOF          R            16.                     101.
FACTOR       R             2.  D                   23.   41.
FLOAT        R            47.       FUNCTION       55.
FORM         R             3.  D                   40.   52.   59.  104.  107.
GDATA        R             6.  C
GRID         R            95.       SUBROUTINE
GSIZE        R             6.  C                   68.
I            I             9.       DATA           34.   35.   52.   54.   59.   61.   79.   80.   81.   82.   83.   84.   85.  106.
                                                  107.  109.  110.  111.  120.  124.  125.
IBEG         I            49.                      51.   52.   53.   56.   58.   59.   60.
ICODE        I             3.  D    DATA            9.   17.   18.   21.   22.  103.  113.
IEND         I            51.                      52.   58.   59.
IHYPSO       I             7.  C                  114.
ILIST        I             6.  C                   68.
INCON        I             7.  CD                 119.  120.
IOUT         I            20.                      21.
IPUN         I             6.  C                   68.
ISWCH        I            15.                      17.   18.
ITYPE        I             6.  C                   23.   41.  105.  109.
J            I           107.                     111.  125.
JNUM         I            30.                      37.   43.   46.   55.   61.   75.   91.
K            I            33.                      48.   78.
KNUM         I            25.                      29.   30.   33.   45.   46.   48.   70.   74.   75.   78.
KODE         I            14.                      17.   18.   19.
KONTUR       I            20.                     100.  113.
KOUNT        I             6.  C                   64.   83.   84.   85.   86.   87.   94.
KTAPE        I             6.  C                   13.   21.
KTR          I            26.                      31.   34.   35.   37.   71.   76.   79.   80.   91.
KTSW         I            27.                      32.   36.   38.   72.   77.   90.   92.
LINES        I             7.  C                  114.
LIST         I           100.                     122.
MAPS         I             7.  C
MATRIX       I           100.                     103.
MYSW         I            63.                      97.
N            I            50.                      57.  112.  113.  122.
NAREA        I            20.                      62.
NCOL         I             6.  C                   68.  105.  107.  109.  111.  125.  126.
NMAP         I            68.                     100.  102.  112.
NN           I            62.
NOBS         I            20.                      24.   26.   29.   30.   42.   43.   45.   46.   69.   71.   74.   75.
NPT          I            20.                      47.   51.   53.   55.   58.   60.
NROW         I             6.  C                   68.  105.  106.  109.  110.  124.  126.
NSTEP        I            47.                      50.   55.   57.
NTAPE        I            20.                      22.
```

```
PRTCON4     R        126.      SUBROUTINE
SDF1        I          5.      FILE           6.    35.    54.    61.    65.    79.
SDF2        I          5.      FILE           8.    12.    23.    34.
SOF3        I          5.      FILE           8.    11.   109.   111.   130.
SYSIN       I          5.      FILE           8.    15.    16.    20.    40.    41.    52.    59.    66.    67.    68.   100.   101.   104.
                                            105.   107.   114.   117.   119.   120.
SYSOT       I          5.      FILE           8.    98.   123.   125.
TITL        R          3. CD                  6.    66.    98.   105.   109.   123.   126.
TOUR        I          4. C                   7.   114.   115.   116.
W           R          3. CD                  6.    85.
WIDTH       R          7. C                 114.
X           R          3. CD                  6.    83.
XMAX        R          6. C                  67.    81.
XMIN        R          6. C                  67.    81.
XT          R          3.  DE                10.    34.    35.    52.    54.    59.    61.    79.    81.    83.
Y           R          3. CD                  6.    84.
YMAX        R          6. C                  67.    82.
YMIN        R          6. C                  67.    82.
YT          R          3.  DE                10.    34.    35.    52.    54.    59.    61.    79.    82.    84.
Z           R          3.  DE                10.    95.   107.   111.   125.   126.
ZMAX        R          7. C                 117.
ZMIN        R          7. C                 117.
ZT          R          3.  DE                10.    34.    35.    52.    54.    59.    61.    79.    85.

 69 SYMBOLS DEFINED

 21 MAXIMUM NUMBER OF REFERENCES

268 TOTAL   NUMBER OF REFERENCES

3.9 AVERAGE NUMBER OF REFERENCES
```

d) LISTING OF SUBROUTINE GRID

```
      SUBROUTINE GRID (Z,NROWZ,NCOLZ)                                   B   2
C     ----------------------------------------------------------------- B   4
C                                SUBROUTINE GRID                        B   6
C     ----------------------------------------------------------------- B   8
C     PURPOSE --                                                        B  10
C          TO INTERPOLATE A SERIES OF IRREGULARLY SPACED THREE-DIMENSIONAL B  12
C     DATA OBSERVATIONS TO PRODUCE A MATRIX OF EQUALLY SPACED (GRIDDED) B  14
C     ELEVATIONS. A WEIGHTED MOVING AVERAGE IS USED.                    B  16
C                                                                       B  18
C     ----------------------------------------------------------------- B  20
C                    THE GCARS SYSTEM                                   B  22
C                    PURDUE UNIVERSITY                                  B  24
C                                                                       B  26
C                                                 A. KEITH TURNER,      B  28
C                                                 CIVIL ENGINEERING,    B  30
C                                                 JUNE 1969,            B  32
C                                                                       B  34
C     ----------------------------------------------------------------- B  36
C     USAGE -                                                           B  38
C          CALL GRID (Z,NROWZ,NCOLZ)                                    B  40
C     WHERE - Z = MATRIX OF GRIDDED VALUES PRODUCED BY THIS SUBROUTINE, B  42
C           - NROWZ = MAXIMUM (DIMENSIONED ) NUMBER OF ROWS IN Z MATRIX. B  44
C           - NCOLZ = MAXIMUM (DIMENSIONED ) NUMBER OF COLUMNS IN Z MATRIX B  46
C                                                                       B  48
C     NOTE -                                                            B  50
C          THIS ROUTINE UTILIZES LABELLED COMMON /GDATA/                B  52
C                                                                       B  54
C     ----------------------------------------------------------------- B  56
C     DESCRIPTION OF CONTROL CARDS -                                    B  58
C          NONE REQUIRED - ALL PARAMETERS SPECIFIED BY CALLING PROGRAM  B  60
C                                                                       B  62
C     ----------------------------------------------------------------- B  64
C     REQUIRED SUBROUTINES -                                            B  66
C          STATS                                                        B  68
C     OPTIONAL SUBROUTINES -                                            B  70
C          NONE                                                         B  72
C                                                                       B  74
C     ----------------------------------------------------------------- B  76
C                                                                       B  78
      DIMENSION X(1000), Y(1000), W(1000), Z(NROWZ,NCOLZ)               B  80
      DIMENSION D(20), NI(20), TITL(7), A(6), B(6), C(6)                B  82
      COMMON /GDATA/ N,X,Y,W,TITL,ROWS,COLS,ITYPE,GSIZE,BND,LIST,IPUN,TA B  84
     1PE,XMAX,XMIN,YMAX,YMIN                                            B  86
      REAL MAXX,MINX,MAXY,MINY,MAXW,MINW,MAXZ,MINZ                      B  88
      INTEGER TAPE,YES,BND,ROWS,COLS                                    B  90
      INTEGER SYSIN,SYSOT,SDF2,SDF3                                     B  92
      DATA SYSIN,SYSOT,SDF2,SDF3/5,6,2,3/                               B  94
      IF (LIST.NE.1.AND.LIST.NE.3) GO TO 10                             B  96
      WRITE (SYSOT,125)                                                 B  98
      WRITE (SYSOT,130) TITL                                            B 100
      DO 5 I=1,N                                                        B 102
5     WRITE (SYSOT,140) I,X(I),Y(I),W(I)                                B 104
10    CALL STATS (N,1,1000,1,X,XBAR,DUM,XSIG,MAXX,MINX)                 B 106
      CALL STATS (N,1,1000,1,Y,YBAR,DUM,YSIG,MAXY,MINY)                 B 108
      CALL STATS (N,1,1000,1,W,WBAR,DUM,WSIG,MAXW,MINW)                 B 110
      WRITE (SYSOT,125)                                                 B 112
      WRITE (SYSOT,145) TITL,N                                          B 114
      IF (BND.EQ.1) GO TO 15                                            B 116
C     ----------------------------------                                B 118
C     BOUNDARIES DEFINED BY DATA                                        B 120
C     ----------------------------------                                B 122
      XMAX=MAXX                                                         B 124
      XMIN=MINX                                                         B 126
      YMAX=MAXY                                                         B 128
      YMIN=MINY                                                         B 130
C     ----------------------------------                                B 132
C     BOUNDARIES SPECIFIED                                              B 134
C     ----------------------------------                                B 136
15    FN=MAXW-MINW                                                      B 138
      WMAX=FN+MAXW                                                      B 140
      WMIN=MINW-FN                                                      B 142
      MAXZ=MAXW                                                         B 144
      MINZ=MINW                                                         B 146
      M=0                                                               B 148
      FN=N+0
      DX=XMAX-XMIN
      DY=YMAX-YMIN
      AREA=DX*DY
      BEST=SQRT(AREA/FN)
      AVEDIS=BEST*1.07346
      WRITE (6,160) XBAR,XSIG,MAXX,MINX,YBAR,YSIG,MAXY,MINY,WBAR,WSIG,MA
     1XW,MINW,AREA,AVEDIS,BEST,GSIZE,ROWS,COLS
C     ------------------------------------
C     DEFINE GRID SIZE
C     ------------------------------------
C     GRID SPACING SPECIFIED
C     ------------------------------------
      IF (GSIZE.LE.0) GO TO 20
      COLS=(1.5+DX/GSIZE)
      ROWS=(1.5+DY/GSIZE)
      M=1
      GO TO 40
C
C     ------------------------------------
C     NUMBER OF COLUMNS SPECIFIED
C     ------------------------------------
20    IF (COLS.LE.1) GO TO 30
25    GSIZE=DX/FLOAT(COLS-1)
      ROWS=(1.5+DY/GSIZE)
      M=1
      GO TO 40
C
C     ------------------------------------
C     NUMBER OF ROWS SPECIFIED
C     ------------------------------------
30    IF (ROWS.LE.1) GO TO 35
      GSIZE=DY/FLOAT(ROWS-1)
      COLS=(1.5+DX/GSIZE)
      M=1
      GO TO 40
C
C     ------------------------------------
C     NO SPECIFICATIONS GIVEN
C     PROGRAM COMPUTES BEST GRID SIZE
C     ------------------------------------
35    GSIZE=BEST
      COLS=(1.5+DX/GSIZE)
      ROWS=(1.5+DY/GSIZE)
40    CONTINUE
      IF (COLS.LE.NCOLZ) GO TO 45
      COLS=NCOLZ
      GO TO 25
C
C     ------------------------------------
C     WRITE FINAL CONTROLS
C     ------------------------------------
45    IF (HND.NE.1) GO TO 50
      WRITE (SYSOT,150)
      GO TO 55
C
50    WRITE (SYSOT,155)
55    WRITE (SYSOT,165)
      IF (M.EQ.1) WRITE (SYSOT,170)
      IF (M.NE.1) WRITE (SYSOT,175)
      WRITE (6,180) XMAX,XMIN,YMAX,YMIN,GSIZE,ROWS,COLS
      IF (LIST.EQ.2.OR.LIST.EQ.3) WRITE (6,185)
C     ------------------------------------
C     PERFORM INTERPOLATION
C     ------------------------------------
      DY=(DY-(ROWS-1.)*GSIZE)/2.0
      DX=(DX-(COLS-1.)*GSIZE)/2.0
      YMAX=YMAX-DY
      XMIN=XMIN+DX
      HGRID=GSIZE/25.0
      FN=(WMAX-MAXW)/2.0
      MAXX=MAXW+FN
      MINX=MINW-FN
C     ------------------------------------
C     LOOP THROUGH GRID ROW BY ROW
C     ------------------------------------
      DO 100 M=1,ROWS
         YP=YMAX-(FLOAT(M-1))*GSIZE
```

```
C     -----------------------------------
C     LOOP THROUGH ROW COL BY COL
C     -----------------------------------
            DO 95 J=1,COLS
               XP=XMIN+(FLOAT(J-1))*GSIZE
               DO 60 I=1,9
60             D(I)=1.E10
               NI(1)=1
               NI(2)=1
               DO 80 I=1,N
                  DIST=((XP-X(I))**2)+((YP-Y(I))**2)
                  IF (DIST.GE.HGRID) GO TO 65
C     -----------------------------------
C     AN ORIGINAL DATA POINT LIES WITHIN 1/25TH GRID
C     SPACING,THEREFORE INTERPOLATION STOPPED FOR THIS POINT
C     -----------------------------------
                  Z(M,J)=W(I)
                  GO TO 90
C
C     -----------------------------------
C     FIND NEAREST POINTS
C     -----------------------------------
65                YES=MIN0(I,8)
                  DO 75 K=1,YES
                     IF (DIST.GE.D(K)) GO TO 75
                     DO 70 JJ=K,YES
                        KK=YES+K-JJ
                        MM=KK+1
                        D(MM)=D(KK)
70                   NI(MM)=NI(KK)
                     D(K)=DIST
                     NI(K)=I
                     GO TO 80
C
75                CONTINUE
80             CONTINUE
C     -----------------------------------
C     COMPUTE WEIGHTED MOVING AVERAGE
C     -----------------------------------
               DUM1=0.0
               PSUM=0.0
               DO 85 I=1,6
                  YES=NI(I)
                  MAXW=1.0/(SQRT(D(I)))
                  PSUM=PSUM+MAXW
85             DUM1=DUM1+W(YES)*MAXW
               DUM6=DUM1/PSUM
               NI1=NI(1)
               DUM2=W(NI1)
               DUM=(DUM2+DUM6)/2.0
               IF (DUM.GT.MAXX.OR.DUM.LT.MINX) Z(M,J)=DUM2
               IF (DUM.LE.MAXX.AND.DUM.GE.MINX) Z(M,J)=DUM
90             CONTINUE
95          CONTINUE
C     -----------------------------------
C     LIST RESULTS
C     -----------------------------------
            IF (LIST.EQ.2.OR.LIST.EQ.3) WRITE (SYSOT,190) (Z(M,I),I=1,COLS)
100     CONTINUE
C     -----------------------------------
C     PUNCH OPTION
C     -----------------------------------
        IF (IPUN.NE.1) GO TO 110
        PUNCH 135, TITL,ROWS,COLS,ITYPE
        DO 105 I=1,ROWS
105     PUNCH 195, (Z(I,J),J=1,COLS)
C     -----------------------------------
C     PLACE GRIDDED VALUES ON TAPE3
C     -----------------------------------
110     IF (TAPE.NE.1) GO TO 120
        WRITE (SDF3) (TITL(I),I=1,4),(TITL(I),I=5,7),COLS,ROWS,ITYPE
        DO 115 I=1,ROWS
115     WRITE (SDF3) (Z(I,J),J=1,COLS)
        END FILE SDF3
120     WRITE (SYSOT,200)
        RETURN
C
```

```
C                                                                       H 460
  125 FORMAT (1H1,55X,29H-----------------------------,/,56X,29HI         I H 462
     1HE GCARS SYSTEM          I,/,56X,29HI PURDUE UNIVERSITY VERSION I,/,56X H 464
     2,29H-----------------------------,///,30X,71HINTERPOLATION OF IRRE H 466
     3GULARLY SPACED OBSERVATIONS ONTO A SPECIFIED GRID.,//)              H 468
  130 FORMAT (1H0,7A10,//,3X,33H ORIGINAL COORDINATE OBSERVATIONS)        H 470
  135 FORMAT (7A10,2I3,I2)                                                H 472
  140 FORMAT (5X,4H I =,I3,7H X(I) =,F10.3,7H Y(I) =,F10.3,7H W(I) =,F10  H 474
     1.3)                                                                 H 476
  145 FORMAT (1H0,7A10,//,3X,I5,13H OBSERVATIONS,//)                      H 478
  150 FORMAT (3X,25H BOUNDARIES PREDETERMINED)                            H 480
  155 FORMAT (3X,32H BOUNDARIES CALCULATED FROM DATA)                     H 482
  160 FORMAT (3X,15HOBSERVED VALUES,//,3X,6HXBAR =,F10.3,6HXSIG =,F10.3, H 484
     16HMAXX =,F10.3,6HMINX =,F10.3,//3X,6HYBAR =,F10.3,6HYSIG =,F10.3,6  H 486
     2HMAXY =,F10.3,6HMINY =,F10.3,//3X,6HWBAR =,F10.3,6HWSIG =,F10.3,6H  H 488
     3MAXW =,F10.3,6HMINW =,F10.3,//3X,6HAREA =,F10.3,8HAVEDIS =,F10.3,6 H 490
     4HDEST =,F10.3,//3X,7HGSIZE =,F10.3,6HROWS =,I4,6HCOLS =,I4,/)      H 492
  165 FORMAT (3X,28H ROWS, COLUMNS, OR GRID SIZE)                         H 494
  170 FORMAT (3X,10H SPECIFIED,/)                                         H 496
  175 FORMAT (3X,21H CALCULATED FROM DATA,/)                              H 498
  180 FORMAT (3X,16H VALUES PLOTTED,/,3X,7H XMAX =,F10.3,3X,7H XMIN =,F  H 500
     110.3,3X,7H YMAX =,F10.3,7H YMIN =,F10.3,/,3X,8H GSIZE =,F10.3,3X,7 H 502
     2H ROWS=,I4,3X,7H COLS =,I4)                                        H 504
  185 FORMAT (1H0,3X,20H INTERPOLATED VALUES)                             H 506
  190 FORMAT (1H0,12F10.3,/(1X,12F10.3))                                  H 508
  195 FORMAT (8F10.3)                                                     H 510
  200 FORMAT (13H0 END OF GRID)                                           H 512
      END                                                                 H 514-
```

e) FORSTAT CROSS-REFERENCE LISTINGS FOR SUBROUTINE GRID

```
SUBROUTINE GRID

 STATEMENT NUMBER    DEFINITION                                        REFERENCES

          5               13.                         12.
         10               14.                          9.
         15               24.                         19.
         20               42.                         37.
         25               43.                         58.
         30               47.                         42.
         35               52.                         47.
         40               55.                         41.    46.    51.
         45               59.                         56.
         50               62.                         59.
         55               63.                         61.
         60               81.                         80.
         65               89.                         88.
         70               96.                         92.
         75              100.                         90.    91.
         80              101.                         84.    99.
         85              108.                        104.
         90              115.                         88.
         95              116.                         78.
        100              118.                         76.
        105              122.                        121.
        110              123.                        119.
        115              126.                        125.
        120              128.                        123.
        125              130.        FORMAT           10.    17.
        130              131.        FORMAT           11.
        135              132.        FORMAT          120.
        140              133.        FORMAT           13.
        145              134.        FORMAT           18.
        150              135.        FORMAT           60.
        155              136.        FORMAT           62.
        160              137.        FORMAT           36.
        165              138.        FORMAT           63.
        170              139.        FORMAT           64.
        175              140.        FORMAT           65.
        180              141.        FORMAT           66.
        185              142.        FORMAT           67.
        190              143.        FORMAT          117.
        195              144.        FORMAT          122.
        200              145.        FORMAT          128.


 40 STATEMENT NUMBERS DEFINED

  3 MAXIMUM NUMBER OF REFERENCES

 45 TOTAL    NUMBER OF REFERENCES

1.1 AVERAGE NUMBER OF REFERENCES
```

```
SUBROUTINE GRID

 LABEL      TYPE     DEFINITION                            REFERENCES

A           R          3.  D
AREA        R         33.                     34.   36.
AVEDIS      R         35.                     36.
B           R          3.  D
BEST        R         34.                     35.   36.   52.
BND         I          4.  C                   6.   19.   59.
C           R          3.  D
COLS        I          4.  C                   6.   36.   38.   42.   43.   49.   53.   56.   57.   66.   69.   78.  117.  120.
                                             122.  124.  126.
D           R          3.  D                  81.   91.   95.   97.  106.
DIST        R         85.                     86.   91.   97.
DUM         R         14.                     15.   16.  112.  113.  114.
DUM1        R        102.                    106.  109.
DUM2        R        111.                    112.  113.
DUM6        R        109.                    112.
DX          R         31.                     33.   38.   43.   49.   53.   69.   71.
DY          R         32.                     33.   39.   44.   48.   54.   68.   70.
E10         R         81.
FLOAT       R         43.      FUNCTION       48.   77.   79.
FN          R         24.                     25.   26.   30.   34.   73.   74.   75.
GDATA       R          4.  C
GSIZE       R          4.  C                  36.   37.   38.   39.   43.   44.   48.   49.   52.   53.   54.   66.   68.   69.
                                              72.   77.   79.
HGRID       R         72.                     86.
I           I         12.                     13.   80.   81.   84.   85.   87.   89.   98.  104.  105.  106.  117.  121.  122.
                                             124.  125.  126.
IPUN        I          4.  C                 119.
ITYPE       I          4.  C                 120.  124.
J           I         78.                     79.   87.  113.  114.  122.  126.
JJ          I         92.                     93.
K           I         90.                     91.   92.   93.   97.   98.
KK          I         93.                     94.   95.   96.
LIST        I          4.  C                   9.   67.  117.
M           I         29.                     40.   45.   50.   64.   65.   76.   77.   87.  113.  114.  117.
MAXW        R          5.                     16.   24.   25.   27.   36.   73.   74.  106.  107.  108.
MAXX        R          5.                     14.   20.   36.   74.  113.  114.
MAXY        R          5.                     15.   22.   36.
MAXZ        R          5.                     27.
MINW        R          5.                     16.   24.   26.   28.   36.   75.
MINX        R          5.                     14.   21.   36.   75.  113.  114.
MINY        R          5.                     15.   23.   36.
MINZ        R          5.                     26.
MINO        I         89.      FUNCTION
MM          I         94.                     95.   96.
N           I          4.  C                  12.   14.   15.   16.   18.   30.   84.
NCOLZ       I          1.  D                   2.   56.   57.
NROWZ       I          1.  D                   2.
```

```
N1        I        3.  D                    62.   83.   96.   98.  105.  110.
N11       I      110.                      111.
PSUM      R      103.                      107.  109.
ROWS      I        4.  C                     6.   36.   39.   44.   47.   48.   54.   66.   68.   76.  120.  121.  124.  125.
SDF2      I        7.        DATA            8.
SDF3      I        7.        FILE            8.  124.  126.  127.
SQRT      R       34.        FUNCTION      106.
STATS     R       14.        SUBROUTINE     15.   16.
SYSIN     I        7.        DATA            8.
SYSOT     I        7.        FILE            8.   10.   11.   13.   17.   18.   60.   62.   63.   64.   65.  117.  128.
TAPE      I        4.  C                     6.  123.
TITL      R        3.  CD                    4.   11.   18.  120.  124.
W         R        2.  CD                    4.   13.   16.   87.  108.  111.
WBAR      R       16.                       36.
WMAX      R       25.                       73.
WMIN      R       26.
WSIG      R       16.                       36.
X         R        2.  CD                    4.   13.   14.   85.
XBAR      R       14.                       36.
XMAX      R        4.  C                    20.   31.   66.
XMIN      R        4.  C                    21.   31.   66.   71.   79.
XP        R       79.                       85.
XSIG      R       14.                       36.
Y         R        2.  CD                    4.   13.   15.   85.
YBAR      R       15.                       36.
YES       I        6.                       89.   90.   92.   93.  105.  108.
YMAX      R        4.  C                    22.   32.   66.   70.   77.
YMIN      R        4.  C                    23.   32.   66.
YP        R       77.                       85.
YSIG      R       15.                       36.
Z         R        1.  D                     2.   87.  113.  114.  117.  122.  126.

 75 SYMBOLS DEFINED

 17 MAXIMUM NUMBER OF REFERENCES

288 TOTAL   NUMBER OF REFERENCES

3.8 AVERAGE NUMBER OF REFERENCES
```

f) LISTING OF SUBROUTINE PRTCON4

1.

```
      SUBROUTINE PRTCON4 (Z,TITL,ROWS,COLS,NROWZ,NCOLZ)
C     -----------------------------------------------------------------
C                          SUBROUTINE PRTCON4
C     -----------------------------------------------------------------
C     PURPOSE -
C
C               TO PRODUCE CONTOUR MAPS ON THE PRINTER.
C
C     -----------------------------------------------------------------
C                   THE GCARS SYSTEM
C                   PURDUE UNIVERSITY
C
C                                               A. KEITH TURNER,
C                                               CIVIL ENGINEERING,
C                                               JUNE 1969.
C     -----------------------------------------------------------------
C     GENERAL INSTRUCTIONS.
C
C          THIS SUBROUTINE IS BASED IN PART ON A MAD LANGUAGE PROGRAM
C     OBTAINED FROM DR. W. R. TOBLER, DEPT. OF GEOGRAPHY, UNIVERSITY OF
C     MICHIGAN, ANN ARBOR.
C          CONTOUR MAPS ARE PRODUCED ON THE PRINTER FROM GRIDDED DATA
C     USING LINEAR INTERPOLATION WITHIN GRID SQUARES.  A SINGLE CHARACTER
C     IS ASSIGNED TO EACH CONTOUR INTERVAL WITH A MAXIMUM OF 10 INTERVALS
C     ALLOWED.
C          ALTERNATIVE DISPLAYS ARE POSSIBLE- CONTOUR LINES MAY BE
C     PRINTED, ALTERNATE CONTOUR BANDS MAY BE PRINTED, OR ALL POINT
C     POSITIONS ON THE MAP MAY BE PRINTED.  CONTOUR INTERVALS CAN BE
C     SPECIFIED IN A VARIETY OF WAYS, AS CAN THE DATA RANGE.  IRREGULARLY
C     SHAPED AREAS CAN BE CONTOURED IF THE GRID POINTS FALLING OUTSIDE
C     THE AREA OF INTEREST ARE GIVEN ARBITRARILY VERY HIGH OR VERY LOW
C     VALUES(THEY MUST BE ONE DATA RANGE ABOVE HIGH OR BELOW LOW).
C          THE SUBROUTINE PREPARES A FREQUENCY TABLE SHOWING THE PERCENT
C     MAP AREA (OR PERCENT AREA OF INTEREST FOR IRREGULAR AREAS) BY NUMER-
C     ICAL INTEGRATION.  THE VALUES MAY BE FURTHER ANALYZED BY SUBROUTINE
C     HYPSO WHICH PERFORMS HYPSOMETRIC (AREA-ALTITUDE) ANALYSIS.
C
C     -----------------------------------------------------------------
C
C     SPECIAL NOTE -
C
C          THE MAXIMUM MAP WIDTH IS 12.7 INCHES, THE WIDTH OF THE PAPER.
C     THE MAXIMUM NUMBER OF COLUMNS OF INPUT DATA IS A FUNCTION OF THE
C     SPECIFIED MAP WIDTH.  THE ROUTINE COMPUTES A PARAMETER =PS= WHICH IS
C     THE (TRUNCATED) INTEGER NUMBER OF PRINTER CHARACTERS WHICH CAN BE
C     PLACED WITHIN A SINGLE MAP COLUMN. PS IS COMPUTED AS FOLLOWS --
C          PS = (COL-COLS)/(COLS-1)
C          WHERE COL = (INTEGER) NUMBER OF CHARACTERS IN THE SPECIFIED
C                      MAP WIDTH. IT EQUALS WIDTH*10.0+2.0
C                COLS = NUMBER OF COLUMNS IN THE MATRIX BEING CONTOURED.
C     DUE TO THE INTEGER TRUNCATION, THE FINAL MAP WILL NEVER EXCEED THE
C     SPECIFIED WIDTH. IF AN INTEGER NUMBER OF CHARACTERS CAN EXACTLY FIT
C     INTO EACH GRID COLUMN THE MAP WILL EQUAL THE SPECIFIED WIDTH, OTHER-
C     WISE IT WILL BE SMALLER. THE VALUE OF PS MUST BE AT LEAST 1, OR THE
C     PLOT WILL BE ABORTED. AT PS = 1 THE GRID SPACING WILL BE AS BELOW .
C                    + + + + + + + + + + + + + + + + + + +
C     AT THIS SPACING THE MAXIMUM NUMBER OF COLUMNS THAT CAN BE INCLUDED
C     WITHIN THE MAXIMUM PAGE WIDTH ( 12.7 INCHES ) IS 64 . THIS IS
C     GREATER THAN 50 , THE PRESENT GCARS STANDARD MAXIMUM SIZE. HOWEVER,
C     IF MORE COLUMNS ARE REQUIRED, OR THE SAME NUMBER ARE DESIRED AT A
C     LARGER SCALE, THE MAP MUST BE MADE IN SECTIONS, USING ONLY PART OF
C     THE DATA IN EACH PASS. BY PROPER SCALING IT IS POSSIBLE TO GET ALL
C     MAPS AT A CONSISTENT SCALE. IT IS ADVISABLE TO ALLOW FOR SOME
C     OVERLAP BY REPEATING SOME COLUMNS.
C
C          PRINTED MAPS WILL BE FREE OF DISTORTION ONLY WHEN THE SCALE
C     SELECTED DEVELOPS A GRID SIZE REPRESENTING UNIT NUMBERS OF CHAR-
C     ACTERS (10 PER INCH) AND ROWS (6 PER INCH).  THE SMALLEST SUCH SIZE
C     IS  1/2  INCH (5 CHARACTERS WIDE BY 3 ROWS HIGH).
C
```

```
C     -----------------------------------------------------------------
C     USAGE -
C                 CALL PRTCON4(Z,TITL,NROW,NCOL,NROWZ,NCOLZ)
C
C           NOTE-
C           CALLING PROGRAM MUST INCLUDE THE FOLLOWING STATEMENTS-
C
C                 INTEGER CON, TOUR
C                 COMMON/MAPS/CON,TOUR, LINES, WIDTH,IHYPSO,INCON(8),
C                 DRANG(25),ZMIN,ZMAX
C
C           THESE VARIABLES CONTROL THE MAPPING FUNCTION AND MUST BE SET TO
C           APPROPRIATE VALUES IN THE CALLING PROGRAM ( SEE PROGRAM MAPPER
C           FOR EXAMPLE ).
C
C     -----------------------------------------------------------------
C     DEFINITION OF ARGUMENTS AND CONTROL VARIABLES
C           (APPROPRIATE VALUES FOR THESE MUST BE SUPPLIED BY CALLING PRO-
C           GRAM)
C
C     A)    ARGUMENTS
C
C           Z             - ARRAY OF GRIDDED VALUES TO BE CONTOURED
C           TITL          - ALPHANUMERIC TITLE 1-80 CHARACTERS
C           NROW          - NUMBER OF ROWS IN ARRAY Z
C           NCOL          - NUMBER OF COLUMNS IN ARRAY Z
C           NROWZ         - MAXIMUM (DIMENSIONED) NUMBER OF ROWS IN ARRAY Z
C           NCOLZ         - MAXIMUM (DIMENSIONED) NUMBER OF COLUMNS IN ARRAY Z
C
C     B)    CONTROL VARIABLES ( AS FOUND IN /MAPS/ )
C
C           CON           - THE NUMBER OF CONTOUR INTERVALS (MAXIMUM = 19).
C                           ( CON = DATA RANGE / DESIRED CONTOUR INTERVAL ).
C           TOUR          - IF TOUR = 0. PROGRAM USES MAXIMUM AND MINIMUM FROM
C                           DATA FOR UPPER AND LOWER CONTOUR LIMITS.
C                           IF TOUR = 1. DESIRED TOP AND BOTTOM CONTOURS READ
C                           IN FROM SPECIAL PROGRAM CARD (SEE BELOW).
C                           IF TOUR = 2. VARIABLE CONTOURS READ IN (LOW TO
C                           HIGH).  IN THIS CASE SET CON EQUAL TO THE NUMBER
C                           OF VALUES TO BE READ IN.
C                           IF TOUR = 3. CONTOUR INTERVAL BECOMES 1/2 STANDARD
C                           DEVIATION ( MAX = +3 SIGMA, MIN = -3 SIGMA ).
C           LINES         - IF LINES = 0, CONTOUR LINES ARE PRINTED.
C                           IF LINES = 1, ALTERNATE (EVEN VALUED) CONTOUR BANDS
C                           ARE PRINTED
C                           IF LINES = 2, ALL BANDS PRINTED (ALL PRINT POSNS).
C           WIDTH         - WIDTH IS MAP WIDTH IN INCHES.  IF GREATER THAN
C                           12.7 OR BLANK, SET TO 10.0
C                           (COL = MAP WIDTH IN CHARACTERS = WIDTH*10.0)
C           IHYPSO        - IF IHYPSO = 1 SUBROUTINE HYPSO CALLED.
C           INCON(8)      - THIS ARRAY CONTAINS THE FORMAT FOR READING THE
C                           IRREGULARLY SPACED CONTOUR LEVELS.  IT IS USED ONLY
C                           WHEN TOUR = 2.
C           DRANG(25)     - THIS ARRAY CONTAINS THE CONTOUR LEVELS.  IT IS
C                           DEVELOPED INTERNALLY EXCEPT WHEN IRREGULAR CONTOUR
C                           LEVELS ARE REQUESTED.  THEN THE VALUES OF DRANG MUS
C                           BE READ IN FROM CONTROL CARD(S) ACCORDING TO THE
C                           FORMAT DESCRIBED BY INCON.  (SEE PROGRAM MAPPER FOR
C                           EXAMPLE)
C           ZMIN          - THE MINIMUM VALUE OF THE Z ARRAY ( TOUR = 0 ), THE
C                           LOWEST DESIRED CONTOUR LEVEL ( TOUR = 1 OR 2 ), OR
C                           MINUS THREE STANDARD DEVIATIONS (TOUR = 3 )
C           ZMAX          - THE MAXIMUM VALUE OF THE Z ARRAY ( TOUR = 0 ), THE
C                           HIGHEST DESIRED CONTOUR LEVEL ( TOUR = 1 OR 2 ), OR
C                           PLUS THREE STANDARD DEVIATIONS ( TOUR = 3 )
C
C     -----------------------------------------------------------------
C
C     DESCRIPTION OF CONTROL CARDS--
C
C           NONE REQUIRED- ALL MAPPING VARIABLES MUST BE SUPPLIED BY CALLIN
C     PROGRAM. (SEE ABOVE)
C
C     -----------------------------------------------------------------
C
C     REQUIRED SUBROUTINES--
C           -STATS
C     OPTIONAL SUBROUTINES--
C           -HYPSO - USED ONLY WHEN IHYPSO = 1
```

```
C     ------------------------------------------------------------------
        DIMENSION TITL(8), SYMTAB(21), PSYM(131), Z(NROWZ,NCOLZ), TABF(25)
        DIMENSION ZPREV(131), SYM(131), CUMH(27)
        COMMON /MAPS/ CON,TOUR,LINES,WIDTH,IHYPSO,INCON(8),DRANG(25),ZMIN,
       1ZMAX
        INTEGER ROWS,COLS,CON,TOUR,COLMAX,COL,PSYM,PS,GRID,ICUT,ILOW,SYM,B
       1LANK,PLUS,MINUS,STAR,SYMTAB
        INTEGER XSTOP,YSTOP
        INTEGER SYSOT
        REAL MINZ,MAXZ,INCHES,INCON
        DATA (SYMTAB(I),I=1,21)/1H0,1H1,1H2,1H3,1H4,1H5,1H6,1H7,1H8,1H9,1H
       1A,1HB,1HC,1HD,1HE,1HF,1HG,1HH,1HI,1HJ,1HK/,BLANK/1H /,PLUS/1H+/,MI
       2NUS/1H-/,STAR/1H*/
        DATA SYSOT/6/
C     ----------------------------------
C     ZERO COUNTERS AND ARRAYS USED IN FREQUENCY TABLE
C     ----------------------------------
        JJ=0
        MM=0
        SUM=0.0
        ILOW=0
        IOUT=0
        DO 5 I=1,25
 5      TABF(I)=0.0
        N=ROWS*COLS
C     ----------------------------------
C       N = NUMBER OF DATA POINTS
C     ----------------------------------
        WRITE (SYSOT,200) TITL,N,COLS,ROWS
        CALL STATS (ROWS,COLS,NROWZ,NCOLZ,Z,ZBAR,ZVAR,ZSIG,MAXZ,MINZ)
C     ----------------------------------
C     DETERMINE CONTOUR LINE ELEVATIONS
C     TOUR VALUE DETERMINES METHOD USED IN DEFINING CONTOURS
C     ----------------------------------
        IF (TOUR.GT.3.OR.TOUR.LE.0) GO TO 25
        GO TO (10,15,20), TOUR
 10     WRITE (SYSOT,205)
        GO TO 30
C
 15     WRITE (SYSOT,210)
        ZMIN=DRANG(1)
        ZMAX=DRANG(CON)
        GO TO 30
C
 20     ZMIN=ZBAR-3.0*ZSIG
        ZMAX=ZBAR+3.0*ZSIG
        CON=12
        WRITE (SYSOT,215)
        GO TO 30
C
 25     WRITE (SYSOT,220)
        ZMIN=MINZ
        ZMAX=MAXZ
 30     WRITE (SYSOT,225) ROWS,COLS,ZBAR,ZSIG,MAXZ,MINZ
C     ----------------------------------
C     CALCULATE MAP WIDTH IN CHARACTERS (COL)
C     ----------------------------------
        IF (WIDTH.LE.0.0) WIDTH=10.0
        IF (WIDTH.GT.12.7) WIDTH=12.7
        COL=WIDTH*10.0+2.0
        PS=(COL-COLS)/(COLS-1)
C     ----------------------------------
C     TEST GRID SIZE--IF GRID SMALLER THAN 1 CHARACTER  BETWEEN COLUMNS,
C     AN ERROR STATEMENT IS PRINTED AND PLOT ABORTED
C     ----------------------------------
        IF (PS.GT.0) GO TO 35
        WRITE (SYSOT,230)
        GO TO 195
C
C     ----------------------------------
C     CALCULATE REQUIRED CONSTANTS
C     ----------------------------------
 35     COLMAX=PS*(COLS-1)+COLS
        YINC=1.0/((FLOAT(PS+1))*0.6)
        GRID=PS+1
        XINC=1.0/FLOAT(GRID)
```

```
          RANGZ=ZMAX-ZMIN
          RHIGH=ZMAX+RANGZ
          RLOW=ZMIN-RANGZ
          IF (CON.EQ.0.OR.CON.GT.19) CON=5
          FCON=CON
          CI=RANGZ/FCON
          IF (TOUR.EQ.2) GO TO 45
          JJJ=CON+1
          DO 40 I=1,JJJ
 40       DRANG(I)=ZMIN+FLOAT(I-1)*CI
 45       CONTINUE
          WRITE (SYSOT,235)
          WRITE (SYSOT,240) ZMIN,ZMAX,CI,GRID,XINC,YINC,CON,RS,COLMAX
C       ------------------------------------
C       WRITE OUT CONTOUR SYMBOL TABLE
C       ------------------------------------
          WRITE (SYSOT,245)
          IF (LINES.EQ.1) WRITE (SYSOT,250)
          WRITE (SYSOT,255)
          IF (LINES.NE.0) GO TO 50
          WRITE (SYSOT,260)
          WRITE (SYSOT,265) (SYMTAB(I),DRANG(I),I=1,CON)
          WRITE (SYSOT,270)
          GO TO 55
C
 50       WRITE (SYSOT,275)
          WRITE (SYSOT,280) (SYMTAB(I),DRANG(I),DRANG(I+1),I=1,CON)
          WRITE (SYSOT,285) DRANG(CON+1)
C       ------------------------------------
C       START MAP PAGE WITH TITLE AT THE TOP
C       ------------------------------------
 55       WRITE (SYSOT,200) TITL,N,COLS,ROWS
          XSTOP=GRID
          GRID=COLS-1
          COL=3
C       ------------------------------------
C       SET UP COLUMN GRID MARKS
C       ------------------------------------
          DO 65 J=1,GRID
              DO 60 I=2,XSTOP
                  SYM(COL)=BLANK
 60           COL=COL+1
              SYM(COL)=PLUS
 65       COL=COL+1
          N=COLMAX+2
          SYM(2)=PLUS
          SYM(1)=BLANK
          SYM(N)=BLANK
C       ------------------------------------
C       PRINT GRID MARKS ACROSS MAP TOP
C       ------------------------------------
          WRITE (SYSOT,290) (SYM(I),I=1,N)
C       ------------------------------------
C       ESTIMATE VALUE OF ALL PRINTING POSITIONS ON MAP
C       ------------------------------------
C         LOOP THROUGH MAP LENGTH, MATRIX ROW BY MATRIX ROW
C       ------------------------------------
          ITOP=1
          IROW=ROWS+1
          DO 185 MM=2,IROW
              YSTOP=1./YINC+.5
              IF (MM.EQ.IROW) YSTOP=1
              M=MM-1
              YP=0.0
              PSYM(1)=PLUS
              PSYM(N)=PLUS
C       ------------------------------------
C       LOOP THROUGH GRID, LINE BY LINE
C       ------------------------------------
          DO 185 KJ=1,YSTOP
              COL=1
              Z1=YP*(Z(MM,1)-Z(M,1))+Z(M,1)
C       ------------------------------------
C         LOOP THROUGH MAP WIDTH,COLUMN BY COLUMN
C       ------------------------------------
              II=COLS-1
              NST=2
```

```
               DO 155 J=1,II
                  JJ=J+1
                  Z2=YP*(Z(MM,JJ)-Z(M,JJ))+Z(M,JJ)
                  ZDELT=Z2-Z1
C     ------------------------------------
C     LOOP THROUGH GRID, CHARACTER BY CHARACTER
C     ------------------------------------
                  XP=0.0
                  DO 150 KK=1,XSTOP
                     JLFT=JLFT-1
                     COL=COL+1
                     ZEST=XP*ZDELT+Z1
C     ------------------------------------
C     ESTIMATED ELEV. FOR CURRENT CHARACTER IS ZEST.
C     CHECK ZEST TO SEE IF IT FALLS WITHIN CONTOUR RANGE.
C     ------------------------------------
                     IF (ZEST.GE.ZMIN.AND.ZEST.LE.ZMAX) GO TO 110
                     IF (ZEST.GT.ZMAX) GO TO 80
                     IF (ZEST.LE.BLOW) GO TO 95
C     ------------------------------------
C     ZEST IS *BELOW LOW*
C     ------------------------------------
                     IF (ITOP.EQ.1.OR.MM.EQ.IROW.OR.JLFT.EQ.1) GO TO 70
                     PSYM(COL)=BLANK
                     GO TO 75
C
70                   PSYM(COL)=MINUS
75                   TLOW=TLOW+1
                     ZPREV(COL)=ZEST
                     ZLAST=ZEST
                     GO TO 145
C
80                   IF (ZEST.GE.BHIGH) GO TO 100
C     ------------------------------------
C     ZEST IS *ABOVE HIGH*
C     ------------------------------------
                     IF (ITOP.EQ.1.OR.MM.EQ.IROW.OR.JLFT.EQ.1) GO TO 85
                     PSYM(COL)=BLANK
                     GO TO 90
C
85                   PSYM(COL)=PLUS
90                   TABE(CON+1)=TABE(CON+1)+1.0
                     ZPREV(COL)=ZEST
                     ZLAST=ZEST
                     GO TO 145
C
C     ------------------------------------
C     ZEST IS IN *NO DATA* RANGE
C     ------------------------------------
95                   PSYM(COL)=MINUS
                     GO TO 105
C
100                  PSYM(COL)=PLUS
105                  IF (ITOP.EQ.1.OR.MM.EQ.IROW.OR.JLFT.EQ.1) PSYM(COL)=STAR
                     TOUT=TOUT+1
                     ZPREV(COL)=ZEST
                     ZLAST=ZEST
                     GO TO 150
C
C     ------------------------------------
C     ESTIMATED ELEV. (ZEST) LIES WITHIN CONTOUR RANGE
C     ASSIGN IT TO APPROPIATE CONTOUR INTERVAL
C     ------------------------------------
110                  I=((ZEST-ZMIN)/CI)+1.
                     TABE(I)=TABE(I)+1.0
                     LVAL=LINES+1
                     IF (ITOP.EQ.1.OR.MM.EQ.IROW.OR.JLFT.EQ.1) LVAL=3
```

```
C     ------------------------------------
C     ASSIGN PRINT CHARACTER SO AS TO PRODUCE REQUESTED FORM OF DISPLAY
C     NOTE-LVAL = LINES + 1
C     ------------------------------------
                  GO TO (115,135,140), LVAL
C     ------------------------------------
C     CONTOUR LINES
C     ------------------------------------
115               DO 120 I=1,CON
                     ZSTEP=URANG(I)
                     SW1=1.
                     SW2=1.
                     SW3=1.
                     SW4=1.
                     IF (ZSTEP.GE.ZLAST.OR.ZSTEP.GE.ZPREV(COL)) SW1=0.
                     IF (ZSTEP.LE.ZEST) SW2=0.
                     IF (ZSTEP.LT.ZLAST.OR.ZSTEP.LT.ZPREV(COL)) SW3=0.
                     IF (ZSTEP.GE.ZEST) SW4=0.
                     IF ((SW1.EQ.0..AND.SW2.EQ.0.).OR.(SW3.EQ.0..AND.SW4.EQ
     1               .0.)) GO TO 125
120               CONTINUE
                  PSYM(COL)=BLANK
                  GO TO 130
C
125               PSYM(COL)=SYMTAB(I)
                  IF (ZPREV(COL).GE.RHIGH.OR.ZLAST.GE.RHIGH) PSYM(COL)=PLUS
                  IF (ZPREV(COL).LE.RLOW.OR.ZLAST.LE.RLOW) PSYM(COL)=MINUS
130               ZLAST=ZEST
                  ZPREV(COL)=ZEST
                  GO TO 145
C
C     ------------------------------------
C     ALTERNATE CONTOUR BANDS
C     ------------------------------------
135               K=I/2
                  IF ((K*2).NE.I) PSYM(COL)=SYMTAB(I)
                  IF ((K*2).EQ.I) PSYM(COL)=BLANK
                  GO TO 145
C
C     ------------------------------------
C     ALL PRINT POSITIONS.
C     ------------------------------------
140               PSYM(COL)=SYMTAB(I)
                  ZPREV(COL)=ZEST
145               SUM=SUM+1.0
150           XP=XP+XINC
              Z1=Z2
155        JLE1=0
C     ------------------------------------
C     THE RIGHT-MOST LINE OF CHARACTERS IS A SPECIAL CASE
C     ------------------------------------
           COL=COL+1
           IF (Z(M,COLS).GE.ZMIN.AND.Z(M,COLS).LE.ZMAX) GO TO 170
           IF (Z(M,COLS).GT.ZMAX) GO TO 160
           IF (Z(M,COLS).LE.RLOW) GO TO 165
           PSYM(COL)=MINUS
           ILOW=ILOW+1
           GO TO 175
C
160        IF (Z(M,COLS).GE.RHIGH) GO TO 165
           PSYM(COL)=PLUS
           TABE(CON+1)=TABE(CON+1)+1.0
           GO TO 175
C
165        PSYM(COL)=STAR
           IOUT=IOUT+1
           GO TO 180
C
170        I=((Z(M,COLS)-ZMIN)/CI)+1.
           TABE(I)=TABE(I)+1.0
           PSYM(COL)=SYMTAB(I)
175        SUM=SUM+1.0
```

```
C     ------------------------------------
C     PRINT OUT LINE JUST PREPARED
C     ------------------------------------
180         WRITE (SYSOT,290) (PSYM(L),L=1,N)
            YP=YP+YINC
            PSYM(1)=BLANK
            PSYM(N)=BLANK
185     ITOP=0
C     ------------------------------------
C     MAP FINISHED, PRINT GRID MARKS ACROSS BOTTOM
C     ------------------------------------
        WRITE (SYSOT,290) (SYM(L),L=1,N)
C     ------------------------------------
C     CALCULATE AND PRINT FREQUENCY TABLE
C     ------------------------------------
        WRITE (SYSOT,295) TOUT
        PTAB=(FLOAT(TLOW)/SUM)*100.0
        CTAB=PTAB
        CUMH(1)=CTAB
        WRITE (SYSOT,300) TLOW,PTAB,CTAB
        DO 190 I=1,CON
           VALUE=DRANG(I)
           VAL1=DRANG(I+1)
           PTAB=(TABF(I)/SUM)*100.0
           CTAB=CTAB+PTAB
           CUMH(I+1)=CTAB
190     WRITE (SYSOT,305) VALUE,VAL1,TABF(I),PTAB,CTAB
        I=CON+1
        PTAB=(TABF(I)/SUM)*100.0
        CTAB=PTAB+CTAB
        CUMH(CON+2)=CTAB
        WRITE (SYSOT,310) VAL1,TABF(I),PTAB,CTAB,SUM,CTAB,CTAB
C     ------------------------------------
C     IF IHYPSO = 1 , PERFORM HYPSOMETRIC ANALYSIS
C     ------------------------------------
        IF (IHYPSO.NE.1) GO TO 195
        CALL HYPSO (DRANG,ZMAX,ZMIN,CON,CUMH,TITL)
195     RETURN
C     -------------------------  F O R M A T S  -------------------------
C
200     FORMAT (1H1,8A10,//,22H MAP IS DEVELOPED FROM,I5,30H GRIDDED VALUE
       1S,CONSISTING OF ,I3,12H COLUMNS BY ,I3,6H ROWS,//)
205     FORMAT (25H CONTOUR LEVELS SPECIFIED)
210     FORMAT (37H VARIABLE CONTOUR INTERVALS SPECIFIED)
215     FORMAT (30H CONTOUR INTERVAL = (1/2 SIGMA)
220     FORMAT (26H CONTOUR LEVELS CALCULATED)
225     FORMAT (13H GRIDDED DATA/,42H LINEAR INTERPOLATION WITHIN GRID SQU
       1ARES /,17H OBSERVED VALUES /,8H ROWS = ,I3,10H    COLS = ,I3,/,8H Z
       2BAR = ,F10.3,10H    ZSIG = ,F10.3,10H    MAXZ = ,F10.3,10H    MINZ =
       3,F10.3)
230     FORMAT (25H TOO MANY COLUMNS IN GRID)
235     FORMAT (1H /,18H VALUES EMPLOYED)
240     FORMAT (8H ZMIN = ,F10.3,10H    ZMAX = ,F10.3,8H    CI = ,F10.3/,8H
       1GRID = ,I5,10H    XINC = ,F10.3,10H    YINC = ,F10.3,/,7H CON = I5,8
       2H    PS = ,I5,12H    COLMAX = ,I5)
245     FORMAT (35H4CONTOUR SYMBOL TABLE IS AS FOLLOWS)
250     FORMAT (43H0(ONLY EVEN SYMBOLS PRINTED IN BODY OF MAP))
255     FORMAT (7H0SYMBOL,11X,5HVALUE)
260     FORMAT (5H0    *,6X,7HNO DATA,/,5H    -,4X,10HBELOW LOW)
265     FORMAT (4X,A1,2X,F12.4)
270     FORMAT (4X,1H+,4X,10HABOVE HIGH)
275     FORMAT (5H0    *,25X,7HNO DATA,/,5H    -,23X,10HBELOW LOW)
280     FORMAT (4X,A1,2X,F12.4,6H  TO  ,F12.4)
285     FORMAT (4X,1H+,2X,F12.4,10H  OR  OVER)
290     FORMAT (1H ,129A1)
295     FORMAT (16H1FREQUENCY TABLE,/,12X,8HINTERVAL,16X,5HUNITS,6X,10HPER
       1CENTAGE,4X,10HCUMULATIVE,/,16X,7HNO DATA,11X,I8)
300     FORMAT (14X,9HBELOW LOW,11X,I8,2(3X,F12.4))
305     FORMAT (1X,F12.4,6H  TO  ,F12.4,3X,F8.0,2(3X,F12.4))
310     FORMAT (1X,F12.4,10H  OR  OVER,11X,F8.0,2(3X,F12.4),/,18X,5HTOTAL,
       111X,F8.0,2(3X,F12.4))
        END
```

g) FORSTAT CROSS-REFERENCE LISTING FOR SUBROUTINE PRTCON4

```
SUBROUTINE PRTCN4.

STATEMENT NUMBER    DEFINITION                                      REFERENCES

        5              17.                    16.
       10              23.                    22.
       15              25.                    22.
       20              29.                    22.
       25              34.                    21.
       30              37.                    24.    29.    33.
       35              45.                    42.
       40              54.                    57.
       45              59.                    55.
       50              70.                    65.
       55              73.                    69.
       60              80.                    78.
       65              82.                    77.
       70             117.                   114.
       75             118.                   116.
       80             122.                   112.
       85             126.                   123.
       90             127.                   125.
       95             131.                   113.
      100             133.                   122.
      105             134.                   132.
      110             139.                   111.
      115             144.                   143.
      120             155.                   144.
      125             158.                   154.
      130             161.                   157.
      135             164.                   143.
      140             168.                   143.
      145             170.                   121.   130.   163.   167.
      150             171.                   107.   148.
      155             173.                   102.
      160             181.                   176.
      165             185.                   177.   181.
      170             188.                   175.
      175             191.                   180.   184.
      180             192.                   187.
      185             196.                    90.    97.
      190             209.                   203.
      195             217.                    44.   215.
      200             218.      FORMAT        19.    73.
      205             219.      FORMAT        23.
      210             220.      FORMAT        25.
      215             221.      FORMAT        32.
      220             222.      FORMAT        34.
      225             223.      FORMAT        37.
      230             224.      FORMAT        43.
      235             225.      FORMAT        60.
      240             226.      FORMAT        61.
      245             227.      FORMAT        62.
      250             228.      FORMAT        63.
      255             229.      FORMAT        64.
      260             230.      FORMAT        66.
      265             231.      FORMAT        67.
      270             232.      FORMAT        68.
      275             233.      FORMAT        70.
      280             234.      FORMAT        71.
      285             235.      FORMAT        72.
      290             236.      FORMAT        87.   192.   197.
      295             237.      FORMAT       198.
      300             238.      FORMAT       202.
      305             239.      FORMAT       209.
      310             240.      FORMAT       214.


 62 STATEMENT NUMBERS DEFINED

  4 MAXIMUM NUMBER OF REFERENCES

 75 TOTAL   NUMBER OF REFERENCES

1.2 AVERAGE NUMBER OF REFERENCES
```

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SUBROUTINE PRICON

 LABEL      TYPE    DEFINITION                              REFERENCES

BLANK        I          5.       DATA        9.   79.   85.   86.  115.  124.  156.  166.  194.  195.
CI           R         64.                  58.   61.  139.  188.
COL          I          6.                  40.   41.   76.   79.   80.   81.   82.   98.  109.  115.  117.  119.  124.  126.
                                           128.  131.  133.  134.  136.  150.  152.  156.  158.  159.  160.  162.  165.  166.
                                           168.  169.  174.  178.  182.  185.  190.
COLMAX       I          5.                  45.   61.   83.
COLS         I          1.                   5.   18.   19.   20.   37.   41.   45.   73.   75.  100.  175.  176.  177.  181.
                                           188.
CON          I          4. C                 5.   27.   31.   52.   53.   56.   61.   67.   71.   72.  127.  144.  183.  203.
                                           210.  213.  216.
CTAB         R        200.                 201.  202.  207.  208.  209.  212.  213.  214.
COMB         R          3.  D              201.  208.  213.  216.
DRANG        R          4. CD               26.   27.   58.   67.   71.   72.  145.  204.  205.  216.
FCON         R         53.                  54.
FLOAT        R         46.       FUNCTION   48.   58.  199.
GRID         I          5.                  47.   48.   61.   74.   75.   77.
HYPSO        R        216.       SUBROUTINE
I            I          9.       DATA       16.   17.   57.   59.   67.   71.   78.   87.  139.  140.  144.  145.  158.  164.
                                           165.  166.  168.  184.  189.  190.  203.  204.  205.  206.  208.  209.  210.  211.
                                           214.
IHYPSO       I          4. C               215.
II           I        100.                 102.
INCHES       R          8.
INCON        R          4. CD                8.
IROW         I         89.                  90.   92.  114.  123.  134.  142.
ITOP         I         88.                 114.  123.  134.  142.  196.
J            I         77.                 102.  103.
JJ           I         11.                 103.  104.
JJJ          I         56.                  57.
JLFT         I        101.                 108.  114.  123.  134.  142.  173.
K            I        164.                 165.  166.
KJ           I         57.
KK           I        107.
L            I        152.                 197.
LINES        I          4. C                63.   65.  141.
LVAL         I        141.                 142.  143.
M            I         93.                  99.  104.  175.  176.  177.  181.  188.
MAPS         I          4. C
MAXZ         R          8.                  20.   36.   37.
MINUS        I          5.       DATA        9.  117.  131.  140.  178.
MINZ         R          8.                  20.   35.   37.
MM           I         12.                  90.   92.   93.   99.  104.  114.  123.  134.  142.
N            I         18.                  19.   73.   83.   86.   87.   96.  192.  195.  197.
NCOLZ        I          1.  D                2.   20.
NROWZ        I          1.  D                2.   20.
PLUS         I          5.       DATA        9.   81.   84.   95.   96.  126.  133.  159.  162.
PS           I          5.                  41.   42.   45.   46.   47.   61.
PSYM         I          2.  D                5.   95.   96.  115.  117.  124.  126.  131.  133.  134.  156.  158.  159.  160.
                                           165.  166.  168.  178.  182.  185.  190.  192.  194.  195.
PTAB         R        199.                 200.  202.  206.  207.  209.  211.  212.  214.
```

```
RANGZ     R     49.                     50.   51.   54.
RHIGH     R     50.                    122.  159.  161.
RLOW      R     51.                    113.  160.  177.
ROWS      I      1.                      5.   18.   19.   20.   37.   73.   89.
STAR      I      5.      DATA            9.  134.  185.
STATS     R     20.      SUBROUTINE
SUM       R     13.                    170.  191.  199.  206.  211.  214.
SW1       R    146.                    150.  154.
SW2       R    147.                    151.  154.
SW3       R    148.                    152.  154.
SW4       R    149.                    153.  154.
SYM       I      3.  D                   5.   79.   81.   84.   85.   86.   87.  197.
SYMTAB    I      2.  D   DATA            5.    9.   67.   71.  158.  165.  168.  190.
SYSOT     I      7.      FILE           10.   19.   23.   25.   32.   34.   37.   43.   60.   61.   62.   63.   64.   66.
                                        67.   68.   70.   71.   72.   73.   87.  192.  197.  198.  202.  209.  214.
TARE      R      2.  D                  17.  127.  140.  183.  189.  206.  209.  211.  214.
TITL      R      1.  D                   2.   19.   73.  216.
TLOW      I      5.                     14.  118.  179.  199.  202.
TOUR      I      4.  C                   5.   21.   22.   55.
TOUT      I      5.                     15.  135.  186.  198.
VALUE     R    204.                    209.
VAL1      R    205.                    209.  214.
WIDTH     R      4.  C                  38.   39.   40.
XINC      R     48.                     61.  171.
XP        R    106.                    110.  171.
XSTOP     I      6.                     74.   78.  107.
YINC      R     46.                     61.   91.  193.
YP        R     94.                     99.  104.  193.
YSTOP     I      6.                     91.   92.   97.
Z         R      1.  D                   2.   20.   99.  104.  175.  176.  177.  181.  188.
ZBAR      R     20.                     29.   30.   37.
ZDELT     R    105.                    110.
ZEST      R    111.                    111.  112.  113.  119.  120.  122.  128.  129.  136.  137.  139.  151.  153.  161.
                                       162.  169.
ZLAST     R    120.                    129.  137.  150.  152.  159.  160.  161.
ZMAX      R      4.  C                  27.   30.   36.   49.   50.   61.  111.  112.  175.  176.  216.
ZMIN      R      4.  C                  26.   29.   35.   49.   51.   55.   61.  111.  139.  176.  188.  216.
ZPREV     R      3.  D                 119.  128.  136.  150.  152.  159.  160.  162.  169.
ZSIG      R     20.                     29.   30.   37.
ZSTEP     R    145.                    150.  151.  152.  153.
ZVAR      R     20.
Z1        R     99.                    105.  110.  172.
Z2        R    104.                    105.  172.

 84 SYMBOLS DEFINED
 35 MAXIMUM NUMBER OF REFERENCES
469 TOTAL   NUMBER OF REFERENCES
5.6 AVERAGE NUMBER OF REFERENCES
```

h) LISTING OF SUBROUTINE HYPSO

```
      SUBROUTINE HYPSO (DRANG,ZMAX,ZMIN,CON,COMM,TITL)
C     ------------------------------------------------------------------
C                            SUBROUTINE HYPSO
C     ------------------------------------------------------------------
C
C     PURPOSE
C          TO PERFORM HYPSOMETRIC ANALYSIS.  HYPSOMETRIC ANALYSIS
C     MEASURES THE RELATIONSHIP BETWEEN AREA AND ALTITUDE.  THE HYPSO-
C     METRIC CURVE IS PREPARED BY PLOTTING RELATIVE HEIGHT (ZMIN = 0.0,
C     ZMAX = 1.0) AGAINST RELATIVE AREA (ENTIRE AREA = 1.0).  THE AREA
C     BELOW THE CURVE IS THE HYPSOMETRIC INTEGRAL.  IT IS A MEASURE OF
C     THE VOLUME BELOW THE SURFACE RELATIVE TO THE VOLUME OF THE ENCLOSING
C     SOLID.  A LARGE HYPSOMETRIC INTEGRAL (ALMOST 1.0) INDICATES YOUTHFUL
C     TOPOGRAPHY. A LOWER VALUE INDICATES MATURE TOPOGRAPHY, AND SMALL
C     VALUES REPRESENT OLD AGE WITH ISOLATED REMNANTS.
C
C          REFERENCE - A.N. STRAHLER, 1952.
C                      HYPSOMETRIC (AREA-ALTITUDE) ANALYSIS OF EROSIONAL
C                           TOPOGRAPHY, GEOLOGICAL SOCIETY OF AMERICA
C                            BULLETIN, VOL. 63, PP 1117-1142.
C     ------------------------------------------------------------------
C                     THE GCARS SYSTEM
C                     PURDUE UNIVERSITY
C
C                                                 A. KEITH TURNER,
C                                                 CIVIL ENGINEERING,
C                                                 JUNE, 1969.
C     ------------------------------------------------------------------
C     USAGE
C               CALL HYPSO ( DRANG, ZMAX, ZMIN, CON , COMM, TITL )
C          WHERE -DRANG = ARRAY CONTAINING CONTOUR LEVELS
C                -ZMAX  = MAXIMUM ELEVATION
C                -ZMIN  = MINIMUM ELEVATION
C                -CON   = NUMBER OF CONTOUR INTERVALS
C                -COMM  = ARRAY CONTAINING THE CUMULATIVE
C                         PERCENTAGES OF THE TOTAL MAP AREA
C                         LYING ABOVE A CONTOUR INTERVAL
C                -TITL  = ANY 80 ALPHANUMERIC CHARACTER TITLE.
C     ------------------------------------------------------------------
C     DESCRIPTION OF CONTROL CARDS
C          ALL DATA SUPPLIED BY PRICON4 .
C     ------------------------------------------------------------------
C     REQUIRED SUBROUTINES
C          NONE
C     OPTIONAL SUBROUTINES
C          NONE
C     ------------------------------------------------------------------
C
        INTEGER SYSOT
        DIMENSION IROW(49,81), RELH(25), RELA(25)
        DIMENSION TITL(8), COMM(27), DRANG(25)
        DATA MINUS,EYE,BLANK,STAR/1H-,1HI,1H ,1H*/
        DATA SYSOT/6/
        REAL IROW,MINUS
        INTEGER CON
C     ----------------------------------
C     MAKE PLOT ALL BLANKS,DRAW BORDERS WITH DOTS,AND PLOT A STAR AT TOP
C     LEFT AND BOTTOM RIGHT CORNERS
C     ----------------------------------
        DO 5 M=1,49
        DO 5 N=1,81
 5      IROW(M,N)=BLANK
        IROW(1,1)=STAR
        DO 10 N=2,81
 10     IROW(1,N)=MINUS
        IROW(49,81)=STAR
        DO 15 N=1,80
 15     IROW(49,N)=MINUS
        DO 20 M=2,48
           IROW(M,1)=EYE
 20     IROW(M,81)=EYE
```

```
C     ------------------------------------                              A 144
C     DETERMINE POSITIONS OF STARS WITHIN THE PLOT                      A 146
C     ------------------------------------                              A 148
         K=CON+1                                                        A 150
         DO 25 I=1,K                                                    A 152
             RELH(I)=(DRANG(I)-ZMIN)/(ZMAX-ZMIN)                        A 154
             RELA(I)=1.0-((CUMR(I)-CUMR(1))/(CUMR(CON+1)-CUMR(1)))      A 156
             N=(49.0-(RELH(I)*49.0))+0.5                                A 158
             J=(RELA(I)*81.0)+0.5                                       A 160
25       IROW(N,J)=STAR                                                 A 162
C     ------------------------------------                              A 164
C     PRINT OUT ALL THE PLOT SEQUENTIALLY                               A 166
C     ------------------------------------                              A 168
         WRITE (SYSOUT,50) TITL                                         A 170
         WRITE (SYSOUT,55)                                              A 172
         WRITE (SYSOUT,60)                                              A 174
         WRITE (SYSOUT,65)                                              A 176
         WRITE (SYSOUT,70) (IROW(1,N),N=1,81)                           A 178
         DO 30 M=2,24                                                   A 180
30       WRITE (SYSOUT,75) (IROW(M,N),N=1,81)                           A 182
         WRITE (SYSOUT,80) (IROW(25,N),N=1,81)                          A 184
         DO 35 M=26,48                                                  A 186
35       WRITE (SYSOUT,75) (IROW(M,N),N=1,81)                           A 188
         WRITE (SYSOUT,85) (IROW(49,N),N=1,81)                          A 190
         WRITE (SYSOUT,65)                                              A 192
         WRITE (SYSOUT,60)                                              A 194
         WRITE (SYSOUT,90)                                              A 196
C     ------------------------------------                              A 198
C     CALCULATE AREA BELOW THE CURVE USING DECIMAL VALUES OF POINTS FOR A 200
C     THE BEST OBTAINABLE ACCURACY.                                     A 202
C     ------------------------------------                              A 204
         AREA=0.                                                        A 206
         DO 40 I=1,CON                                                  A 208
             A=((RELH(I)+RELH(I+1))*(RELA(I)-RELA(I+1)))/2.0            A 210
40       AREA=AREA+A                                                    A 212
         WRITE (SYSOUT,95) AREA                                         A 214
C     ------------------------------------                              A 216
C     WRITE OUT COORDINATES OF HYPSOMETRIC CURVE                        A 218
C     ------------------------------------                              A 220
         WRITE (SYSOUT,100)                                             A 222
         DO 45 I=1,CON                                                  A 224
45       WRITE (SYSOUT,105) I,RELA(I),RELH(I)                           A 226
         RETURN                                                         A 228
C                                                                       A 230
50       FORMAT (1H1,22HHYPSOMETRIC CURVE FOR ,8A10)                    A 232
55       FORMAT (1H ,8HREL. HT./)                                       A 234
60       FORMAT (1H ,8X,3H0.0,37X,3H0.5,37X,3H1.0)                      A 236
65       FORMAT (1H ,9X,1H+,39X,1H+,39X,1H+)                            A 238
70       FORMAT (1H ,4X,5H1.0 +,81A1,5H+ 1.0)                           A 240
75       FORMAT (1H ,9X,81A1)                                           A 242
80       FORMAT (1H ,4X,5H0.5 +,81A1,5H+ 0.5)                           A 244
85       FORMAT (1H ,4X,5H0.0 +,81A1,5H+ 0.0)                           A 246
90       FORMAT (1H ,44X,13HRELATIVE AREA/)                             A 248
95       FORMAT (1H ,77HTHE HYPSOMETRIC INTEGRAL FOR THE ABOVE CURVE ( THE   A 250
        1AREA BELOW THE CURVE ) IS ,F6.4)                               A 252
100      FORMAT (1H1,50HCALCULATED VALUES OF HYPSOMETRIC CURVE COORDINATES,  A 254
        1//,5X,12HPOINT NUMBER,5X,6HA-AXIS,10X,6HH-AXIS)                A 256
105      FORMAT (1H ,10X,I2,10X,F6.4,10X,F6.4)                          A 258
         END                                                            A 260-
```

i) FORSTAT CROSS-REFERENCE LISTINGS FOR SUBROUTINE HYPSO

```
SUBROUTINE HYPSO

STATEMENT NUMBER   DEFINITION                          REFERENCES

       5               11.                  9.    15.
      10               14.                 13.
      15               17.                 16.
      20               20.                 18.
      25               27.                 22.
      30               34.                 33.
      35               37.                 36.
      40               45.                 43.
      45               49.                 48.
      50               51.     FORMAT      28.
      55               52.     FORMAT      29.
      60               53.     FORMAT      30.    40.
      65               54.     FORMAT      31.    39.
      70               55.     FORMAT      32.
      75               56.     FORMAT      34.    37.
      80               57.     FORMAT      35.
      85               58.     FORMAT      38.
      90               59.     FORMAT      41.
      95               60.     FORMAT      46.
     100               61.     FORMAT      47.
     105               62.     FORMAT      49.
```

```
 21 STATEMENT NUMBERS DEFINED

  2 MAXIMUM NUMBER OF REFERENCES

 25 TOTAL    NUMBER OF REFERENCES

1.2 AVERAGE NUMBER OF REFERENCES
```

```
SUBROUTINE EYES
           -----
 LABEL      TYPE     DEFINITION                       REFERENCES

A            R          44.                 45.
AREA         R          42.                 45.   46.
BLANK        R           5.        DATA     11.
COM          I           1.                  8.   21.   24.   43.   48.
CURR         R           1.                  4.   24.
DRAG         R           1.                  4.   23.
EYF          R           5.        DATA     19.   21.
I            I          22.                 23.   24.   25.   26.   43.   44.   45.   47.
IROW         I           4.   D              7.   11.   12.   14.   15.   17.   19.   23.   27.   32.   34.   35.   37.   38.
K            I          21.                 22.
M            I           9.                 11.   18.   19.   20.   25.   27.   33.   34.   36.   47.
MINUS        R           5.        DATA      7.   14.   17.
N            I         100.                 11.   13.   14.   16.   17.   20.   27.   32.   34.   35.   37.   38.
RELA         R           3.   D             24.   26.   44.   49.
RELB         R           3.   D             23.   25.   44.   49.
STAR         R           4.        DATA     12.   15.   27.
SYSOT        I           2.        FILE      6.   28.   29.   30.   31.   32.   34.   35.   37.   38.   39.   40.   41.   46.
                                            47.   49.
TITLE        R           1.   D              4.   24.
ZMAX         R           1.                 23.
ZMIN         R           1.                 23.

 20 SYMBOLS DEFINED
 16 MAXIMUM NUMBER OF REFERENCES
 94 TOTAL NUMBER OF REFERENCES
4.7 AVERAGE NUMBER OF REFERENCES
```

j) LISTING OF SUBROUTINE STATS

```
      SUBROUTINE STATS (ROWS,COLS,II,JJ,X,XBAR,XVAR,XSIG,XMAX,XMIN)     STA    2
C                              SUBROUTINE STATS                         STA    4
C    -------------------------------------------------------------------STA    6
C    PURPOSE -                                                          STA    8
C    TO CALCULATE STATISTICAL MEASURES OF ONE OR TWO DIMENSIONAL DATA   STA   10
C    ARRAYS. MEASURES DETERMINED ARE 1)MEAN,2)VARIANCE,3)STANDARD DEVIA-STA   12
C    TION,4)MAXIMUM VALUE,5)MINIMUM VALUE.                              STA   14
C    -------------------------------------------------------------------STA   16
C    USAGE -                                                            STA   18
C          CALL STATS(ROWS,COLS,II,JJ,X,XBAR,XVAR,XSIG,XMAX,XMIN)       STA   20
C                                                                       STA   22
C        ROWS - NUMBER OF ROWS IN ARRAY BEING ANALYZED.(INTEGER VALUE)  STA   24
C        COLS - NUMBER OF COLUMNS IN ARRAY BEING ANALYZED.(INTEGER VALUE)STA  26
C        II - MAXIMUM NUMBER OF ROWS ALLOWED FOR ARRAY BEING ANALYZED.  STA   28
C        JJ - MAXIMUM NUMBER OF COLUMNS ALLOWED FOR ARRAY BEING ANALYZED.STA  30
C        X - DATA ARRAY BEING ANALYZED.                                 STA   32
C        XBAR - MEAN OF ARRAY.                                          STA   34
C        XVAR - VARIANCE OF ARRAY.                                      STA   36
C        XSIG - STANDARD DEVIATION OF ARRAY.                            STA   38
C        XMAX - MAXIMUM VALUE OF ARRAY.                                 STA   40
C        XMIN - MINIMUM VALUE OF ARRAY.                                 STA   42
C                                                                       STA   44
C    -------------------------------------------------------------------STA   46
C                                                                       STA   48
C        DESCRIPTION OF CONTROL CARDS                                   STA   50
C                 -NONE REQUIRED                                        STA   52
C                                                                       STA   54
C    -------------------------------------------------------------------STA   56
C                                                                       STA   58
C        REQUIRED SUBROUTINES--                                         STA   60
C                 -NONE                                                 STA   62
C        OPTIONAL SUBROUTINES--                                         STA   64
C                 -NONE                                                 STA   66
C                                                                       STA   68
C    -------------------------------------------------------------------STA   70
C                                                                       STA   72
C                                                                       STA   74
      INTEGER ROWS,COLS                                                 STA   76
      DIMENSION X(II,JJ)                                                STA   78
      FNO=ROWS*COLS                                                     STA   80
      XSQR=0.0                                                          STA   82
      XSUM=0.0                                                          STA   84
      XMAX=X(1,1)                                                       STA   86
      XMIN=X(1,1)                                                       STA   88
      DO 5 I=1,ROWS                                                     STA   90
      DO 5 J=1,COLS                                                     STA   92
         IF (X(I,J).GT.XMAX) XMAX=X(I,J)                                STA   94
         IF (X(I,J).LT.XMIN) XMIN=X(I,J)                                STA   96
         XSUM=XSUM+X(I,J)                                               STA   98
5     XSQR=XSQR+X(I,J)*X(I,J)                                           STA  100
      XBAR=XSUM/FNO                                                     STA  102
      XVAR=(XSQR-2.0*XBAR*XSUM+FNO*XBAR*XBAR)/FNO                       STA  104
      XSIG=SQRT(XVAR)                                                   STA  106
      RETURN                                                            STA  108
      END                                                               STA  110-
```

k) FORSTAT CROSS-REFERENCE LISTINGS FOR SUBROUTINE STATS

```
SUBROUTINE STATS

 STATEMENT NUMBER   DEFINITION                                REFERENCES

        5              14.                   9.   10.


┌─────────────────────────────────────────┐
│   1 STATEMENT NUMBERS DEFINED           │
│                                         │
│   2 MAXIMUM NUMBER OF REFERENCES        │
│                                         │
│   2 TOTAL    NUMBER OF REFERENCES       │
│                                         │
│ 2.0 AVERAGE NUMBER OF REFERENCES        │
└─────────────────────────────────────────┘
```

```
SUBROUTINE STATS

 LABEL       TYPE      DEFINITION                                 REFERENCES

COLS          I           1.                        2.     4.    10.
FNU           R           4.                       15.    16.
I             I           9.                       11.    12.    13.    14.
II            I           1.   D                    3.
J             I          10.                       11.    12.    13.    14.
JJ            I           1.   D                    3.
ROWS          I           1.                        2.     4.     9.
SQRT          R          17.        FUNCTION
X             R           1.   D                    3.     7.     8.    11.    12.    13.    14.
XBAR          R           1.                       15.    16.
XMAX          R           1.                        7.    11.
XMIN          R           1.                        6.    12.
XSIG          R           1.                       17.
XSQR          R           5.                       14.    16.
XSUM          R           6.                       13.    15.    16.
XVAR          R           1.                       16.    17.


┌─────────────────────────────────────────┐
│  16 SYMBOLS DEFINED                     │
│                                         │
│   7 MAXIMUM NUMBER OF REFERENCES        │
│                                         │
│  39 TOTAL    NUMBER OF REFERENCES       │
│                                         │
│ 2.4 AVERAGE NUMBER OF REFERENCES        │
└─────────────────────────────────────────┘
```

I) LISTING OF PROGRAM CONTUR

1.

```
      PROGRAM CONTUR(INPUT,OUTPUT,PLOT,TAPE3,TAPE5=INPUT,TAPE6=OUTPUT)
C     ----------------------------------------------------------------
C                            PROGRAM CONTUR
C     ----------------------------------------------------------------
C
C     PURPOSE -
C           1) PLOT CONTOUR MAPS OF GRIDDED DATA ON THE CALCOMP PLOTTER.
C     THIS PROGRAM IS BASED ON A FORTRAN II PROGRAM WRITTEN BY FRANK J.
C     REES, UNIVERSITY OF MICHIGAN DEPARTMENT OF GEOGRAPHY.
C
C     ----------------------------------------------------------------
C                    THE GCARS SYSTEM
C                    PURDUE UNIVERSITY
C
C                                              A. KEITH TURNER,
C                                              CIVIL ENGINEERING,
C                                              JUNE 1969.
C     ----------------------------------------------------------------
C                            GENERAL INSTRUCTIONS
C                            --------------------
C
C           THIS PROGRAM CAN PRODUCE MAPS TO ANY SCALE WITHIN THE LIMITS
C     OF THE PLOTTER PAPER WIDTH (MAXIMUM = 28 INCHES).
C
C           MANY OPTIONS ARE AVAILABLE AND CAN BE SPECIFIED THROUGH THE USE
C     OF CONTROL CARDS. THE USER MAY SPECIFY CONTOURS AT REGULAR OR IRREG-
C     ULAR INTERVALS,AND MAY TRANSFORM MAP COORDINATES BY TRANSLATION OR
C     ROTATION ABOUT ANY OF THE THREE MAJOR AXES ( X,Y,OR Z).
C
C           THE PROGRAM CAN PRODUCE ISOMETRIC BLOCK DIAGRAMS OF THE CONTOUR
C     MAPS BY ROTATING THE DATA ABOUT ALL THREE AXES BEFORE PLOTTING. THE
C     USE OF A PERSPECTIVE OPTION IN COMBINATION WITH TRANSLATION WILL
C     ALLOW THE PLOTTING OF LEFT AND RIGHT VIEWS FOR STEREOSCOPIC ( 3-D)
C     EFFECTS.
C
C           THE PROGRAM IS CAPABLE OF PLOTTING A NUMBER OF DIFFERENT MAPS
C     OF A SINGLE SET OF DATA, EACH INVOLVING DIFFERENT MAP SCALES,CONTOUR
C     INTERVALS,ROTATIONS OR TRANSLATIONS, WITHOUT REREADING THE DATA.
C     VALUES OF CONTOUR LINE COORDINATES ARE CALCULATED AND STORED ON A
C     SCRATCH TAPE. THESE VALUES ARE MODIFIED AND PLOTTED FOR EACH MAP
C     REQUESTED SO THAT THE CALCULATIONS ARE MINIMIZED AND THE PLOTTING
C     OF MULTIPLE MAPS IS EFFICIENT.
C
C     ----------------------------------------------------------------
C
C     TAPE REQUIREMENTS -
C
C           1) A SCRATCH TAPE ( TAPE3 ) IS USED TO STORE CONTOUR LINE COORD
C              -INATES PRIOR TO PLOTTING.
C           2) A PLOT TAPE IS REQUIRED.
C
C     ----------------------------------------------------------------
C
C     DESCRIPTION OF CONTROL CARDS --
C
C           SPECIAL NOTE -
C
C     EACH CONTROL CARD CONTAINS A CONTROL INTEGER (ICON) IN COLUMNS 1-2.
C     SOME OPERATIONS REQUIRE INPUT DATA IN THE FORM OF VARIABLES AND/OR
C     DATA ON ADDITIONAL CARDS. ANY VARIABLES REQUIRED SHOULD BE PLACED
C     IN COLUMNS 3-12,13-22,23-32,33-42, ETC WITH DECIMAL POINTS PUNCHED.
C     WHEN THE CONTROL INTEGER INDICATES THAT ADDITIONAL CARDS ARE NECESS-
C     ARY FOR A COMPLETE OPERATION, THESE CARDS SHOULD FOLLOW IMMEDIATELY.
C     ----------------------------------------------------------------
C     ICON                           REMARKS
C     ----                           -------
C     01      OPER. 1 -- READ AND CONTOUR DATA MATRIX
C           VARIABLES-1)NUMBER OF ROWS
C                     2)NUMBER OF COLUMNS
C                     3)WIDTH OF MAP IN INCHES
C                     4)SCALE FACTOR FOR Z VALUES (Z=Z/ZSCALE) (IF BLANK=1)
C           ADDL CARDS- THE DATA MATRIX IS READ IN ROW BY ROW FROM TOP TO
C                     BOTTOM ( EACH ROW IS SCANNED FROM LEFT TO RIGHT).
C                     THE MATRIX IS READ ACCORDING TO A PREVIOUSLY DEFINED
C                     FORMAT (SEE ICON=19). MAX. MATRIX SIZE IS 100X100 .
C
```

```
C     02    OPERATION-ROTATE THE VIEWING POSITION OF THE SURFACE THETA        A 154
C                     DEGREES IN THE X DIRECTION.                             A 156
C           VARIABLES=1) THETA IN DEGREES.                                    A 158
C           ADDL CARDS=  NONE                                                 A 160
C                                                                             A 162
C     03    OPERATION-ROTATE THE VIEWING POSITION OF THE SURFACE THETA        A 164
C                     DEGREES IN THE Y DIRECTION.                             A 166
C           VARIABLES=1) THETA IN DEGREES.                                    A 168
C           ADDL CARDS=  NONE                                                 A 170
C                                                                             A 172
C     04    OPERATION-ROTATE THE VIEWING POSITION OF THE SURFACE THETA        A 174
C                     DEGREES IN THE Z DIRECTION.                             A 176
C           VARIABLES=1) THETA IN DEGREES.                                    A 178
C           ADDL CARDS=  NONE                                                 A 180
C                                                                             A 182
C     05    OPERATION-CALL SUBROUTINE PROJ FOR USER-DEFINED MODIFICATIONS.    A 184
C           VARIABLES= NONE                                                   A 186
C           ADDL CARDS=  NONE                                                 A 188
C                                                                             A 190
C     06    OPERATION-PLOT USERS NAME AND ACCOUNT NUMBER ON PLOT.             A 192
C           VARIABLES= NONE                                                   A 194
C           ADDL CARDS= NAME AND ACCOUNT NUMBER                               A 196
C                                                                             A 198
C     07    OPERATION-IDENTIFY CONTOUR LEVELS BY PLOTTING THEIR ELEVATIONS.   A 200
C           VARIABLES=1)HEIGHT OF NUMBERS (IN INCHES )                        A 202
C           ADDL CARDS= A 10-CHARACTER FORMAT IN COLS1-10,GIVING FORMAT       A 204
C                        FOR ELEVATIONS- USED TO SPECIFY NUMBER OF DECIMALS.  A 206
C                                                                             A 208
C     08    OPERATION-PLOT CONTOURS WITH PERSPECTIVE TRANSFORMATION TO PROD   A 210
C                     -UCE LEFT OR RIGHT STEREO MODELS.                       A 212
C           VARIABLES=1)DISTANCE TO PERSPECTIVE PLANE.                        A 214
C                     2)DISTANCE TO OBJECT PLANE.                             A 216
C           ADDL CARDS=  NONE                                                 A 218
C                                                                             A 220
C     10    OPERATION-TRANSLATION OF CONTOUR COORDINATES.                     A 222
C           VARIABLES=1)TRANSLATION OF X IN INCHES(NOT SCALED,TRUE MEASURE)   A 224
C                     2)TRANSLATION OF Y IN INCHES(NOT SCALED,TRUE MEASURE)   A 226
C                     3)TRANSLATION OF Z IN INCHES(NOT SCALED,TRUE MEASURE)   A 228
C           ADDL CARDS=  NONE                                                 A 230
C                                                                             A 232
C     11    OPERATION= DEFINE PLOTTER TAPE AS OTHER THAN NORMAL NUMBER.       A 234
C           VARIABLES=1) PLOTTER TAPE NUMBER                                  A 236
C           ADDL CARDS=  NONE                                                 A 238
C                                                                             A 240
C     12    OPERATION= READ TITLE FOR PLOT(PLOTTED AT TOP OF MAP).            A 242
C           VARIABLES=1)DISTANCE FROM LEFT EDGE OF PLOT TO START OF TITLE     A 244
C                       ( IN INCHES ).                                        A 246
C                     2)HEIGHT OF TITLE LETTERS.                              A 248
C           ADDL CARDS= TITLE PUNCHED IN COLUMNS 1-80                         A 250
C                                                                             A 252
C     13    OPERATION= TERMINATE PLOT TAPE                                    A 254
C           VARIABLES= NONE                                                   A 256
C           ADDL CARDS=  NONE                                                 A 258
C                                                                             A 260
C     14    OPERATION= READ LABELS AND COORDINATES(MAX. PER PLOT = 10).       A 262
C           VARIABLES=1) X COORDINATE OF LABEL                                A 264
C                     2) Y COORDINATE OF LABEL                                A 266
C                     3) Z COORDINATE OF LABEL                                A 268
C                     4) HEIGHT OF LABEL LETTERS.                             A 270
C           ADDL CARDS= A LABEL PUNCHED IN COLUMNS 1-36                       A 272
C                                                                             A 274
C     15    OPERATION-DEFINE REGULARLY SPACED CONTOURS.                       A 276
C           VARIABLES=1)STARTING CONTOUR                                      A 278
C                     2) CONTOUR INTERVAL                                     A 280
C                     3) FINAL (HIGHEST) CONTOUR                              A 282
C           ADDL CARDS=  NONE                                                 A 284
C                                                                             A 286
C     16    OPERATION-REDEFINE CONTOUR INTERVALS FOR SAME DATA.               A 288
C           VARIABLES= SAME AS FOR ICON=15                                    A 290
C                                                                             A 292
C     17    OPERATION-DEFINE IRREGULARLY SPACED CONTOURS.                     A 294
C           VARIABLES=1)NCONT=NUMBER OF CONTOURS.                             A 296
C           ADDL CARDS=1)FORMAT OF CONTOURS                                   A 298
C                      2)CONTOUR LEVELS AS DEFINED ABOVE.                     A 300
C                                                                             A 302
C     18    OPERATION= SPECIFY WIDTH OF PAPER( 11 OR 28 INCHES)               A 304
C           VARIABLES=1) WIDTH OF PAPER                                       A 306
C           ADDL CARDS=  NONE                                                 A 308
```

```
C                                                                       A 310
C   19   OPERATION- SPECIFY FORMAT OF DATA                              A 312
C        VARIABLES- NONE                                                A 314
C        ADDL CARDS-FORMAT OF DATA MATRIX IN COLUMNS 1-80               A 316
C                                                                       A 318
C   20   OPERATION-PLOT MAP ACCORDING TO ALL CONTROLS GIVEN SINCE LAST  A 320
C                   CALL TO PLOT (LAST NCON=20)                         A 322
C        VARIABLES- NONE                                                A 324
C        ADDL CARDS- NONE                                               A 326
C                                                                       A 328
C   21   OPERATION- CHANGE WIDTH OF PLOTTED MAP (CHANGE SCALE)          A 330
C        VARIABLES-1) NEW WIDTH IN INCHES                               A 332
C        ADDL CARDS- NONE                                               A 334
C   ----------------------------------------------------------------    A 336
C   COMMENTS AND RESTRICTIONS                                           A 338
C        PRIOR TO READING IN DATA MATRIX, THE FORMAT(NCON=19)AND CONTOUR A 340
C   INTERVALS(NCON=15 OR 17) MUST BE DEFINED.                           A 342
C        BEFORE CALL TO PLOT (NCON=20) PAPER WIDTH (NCON=18) AND ACCOUNT A 344
C   CODE (NCON=08) MUST BE DEFINED. PLOTTING THE MAP RESETS ALL CONTROLS A 346
C        TO PLOT A NEW SET OF DATA USE NCON=1 WITH OR WITHOUT A NEW     A 348
C   FORMAT OR CONTOURING CONTROLS.                                      A 350
C   ----------------------------------------------------------------    A 352
C                                                                       A 354
C                                                                       A 356
C   REQUIRED SUBROUTINES -                                              A 358
C        A) CALCOMP SUBROUTINES                                         A 360
C        - PLOT - INCLUDING THE FOLLOWING ENTRY POINTS -                A 362
C             PLOTS,SYMBOL,NUMBER,FACTOR,WHERE,LINE                     A 364
C             THESE ARE STANDARD CALCOMP ROUTINES AS DESCRIBED IN THEIR A 366
C             MANUALS , EXCEPT FOR NUMBER WHICH HAS BEEN MODIFIED AT    A 368
C             PURDUE AS FOLLOWS --                                      A 370
C             CALL NUMBER (X,Y,HEIGHT,NUM,ANGLE,FORMAT)                 A 372
C             X AND Y - THE STARTING COORDINATES OF THE LOWER LEFT-HAND A 374
C                       CORNER OF THE FIRST CHARACTER IN THE STRING.    A 376
C             HEIGHT  - THE DESIRED HEIGHT IN INCHES OF THE CHARACTERS. A 378
C             NUM     - A CONSTANT, VARIABLE IDENTIFIER, OR EXPRESSION  A 380
C                       WHOSE VALUE IS TO BE PLOTTED.                   A 382
C             ANGLE   - THE ANGLE IN DEGREES COUNTERCLOCKWISE FROM THE  A 384
C                       +X DIRECTION AT WHICH THE NUMBERS ARE TO BE     A 386
C                       PLOTTED.                                        A 388
C             FORMAT  - A HOLLERITH STRING, NO MORE THAN 10 CHARACTERS, A 390
C                       GIVING THE FORTRAN IV FORMAT BY WHICH NUM IS TO A 392
C                       BE CONVERTED FOR PLOTTING ( USED TO GIVE NUMBER A 394
C                       OF DECIMAL PLACES ).                            A 396
C   NOTE-                                                               A 398
C        PURDUE HAS IMPLEMENTED A COPYPLT LIBRARY ROUTINE WHICH PREPARES A 400
C        PLOT TAPES FOR PLOTTING.                                       A 402
C        B) OTHER ROUTINES                                              A 404
C        - SCAN -SCANS DATA TO LOCATE CONTOURS.                         A 406
C        - TRACE -TRACES OUT CONTOUR LINE.                              A 408
C        - CALC -PERFORMS INTERPOLATIONS TO LOCATE LINES.               A 410
C        - DRAFT -PERFORMS ROTATIONS AND TRANSLATIONS,WRITES PLOT TAPE. A 412
C                                                                       A 414
C   OPTIONAL SUBROUTINES -                                              A 416
C        - PROJ - A DUMMY SUBROUTINE TO ALLOW THE ADDITION OF NEW USER  A 418
C                 MODIFICATIONS.                                        A 420
C   ----------------------------------------------------------------    A 422
C                                                                       A.424
      DIMENSION AM(100,100), REC(800), X(1500), Y(1500), IPT(3,3), INX(8 A 426
     1), INY(8), IOP(20), XL(10), YL(10), ZL(10), LAB(10,6), DX(2), DY(2 A 428
     2), DZ(2), HT(10), CTHETA(4), STHETA(4), TEMP(6), FMT(8), Z(1500),  A 430
     3ITT(8), CFMT(12), VCON(20), WORK(1024)                            A 432
      DIMENSION USER(8)                                                 A 434
      COMMON AI,IT,NI,IA,IY,IDX,IDY,ISS,II,IV,NP,N,JI,PY,REC,CV,X,Y,IPT, A 436
     1INX,INY,DL,AM,IOP,DP,DD,ILAB,XL,YL,ZL,LAB,DX,DY,DZ,AMAX,HT,SCALE,Y A 438
     2MAX,CTHETA,STHETA,FMT,FNN,FN,M,CL,D,NLINES,NCURV,Z,ITT,WORK       A 440
      COMMON MAXX,MAXY,MINX,MINY,SIZE                                   A 442
      COMMON /SCALE/IIIHT,CNUMB,DECI,IIIEOU                             A 444
      REAL MAXX,MINX,MAXY,MINY                                          A 446
      NPLOT=1                                                           A 448
      IOP(1)=1                                                          A 450
      NLINES=0                                                          A 452
      ISTAP=5                                                           A 454
      D=0.                                                              A 456
      ILAB=0                                                            A 458
      REWIND 3                                                          A 460
      DO 5 I=2,20                                                       A 462
    5 IOP(I)=0                                                          A 464
      DDDDDD=0.                                                         A 466
   10 READ (5,245) NCON,(TEMP(I),I=1,6)                                 A 468
      WRITE (6,250) NCON,(TEMP(I),I=1,6)                                A 470
      IF (NCON.LE.0.OR.NCON.GT.21) GO TO 235                            A 472
      GO TO (15,50,50,50,55,60,65,70,70,85,90,95,100,105,125,130,135,140 A 474
     1,145,150,210), NCON                                               A 476
C                                                                       A 478
```

```
C     ------------------------------------                A 480
C NCOL=1                                                  A 482
C     ------------------------------------                A 484
15        M=TEMP(1)                                       A 486
          NN=TEMP(2)                                      A 488
          TEMP(1)=TEMP(2)-1.                              A 490
          SCALE=TEMP(1)/TEMP(3)                           A 492
          IF (TEMP(4).EQ.0.) TEMP(4)=1.                   A 494
          ZSCALE=TEMP(4)                                  A 496
          FM2=FLOAT(M)/2.                                 A 498
          FNN=FLOAT(NN)/2.                                A 500
          YMAX=(FM2/SCALE)+2.5                            A 502
          XMAX=(FNN/SCALE)+2.5                            A 504
          MAXX=0.                                         A 506
          MAXY=0.                                         A 508
          MINX=1.E15                                      A 510
          MINY=1.E15                                      A 512
          IF (IOP(1).EQ.0) GO TO 20                       A 514
          IOP(15)=1                                       A 516
          IOP(19)=1                                       A 518
20        IOP(1)=1                                        A 520
          IF (IOP(19).EQ.0) GO TO 220                     A 522
          DO 25 I=1,M                                     A 524
25        READ (ISTAR,FMT) (A1(J,I),J=1,NN)               A 526
          WRITE (3,FMT) ((A1(J,I),J=1,NN),I=1,M)          A 528
          REWIND 3                                        A 530
          IF (IOP(15).EQ.0) GO TO 225                     A 532
          IF (IOPV.EQ.0) GO TO 35                         A 534
C                                                         A 536
C     ------------------------------------                A 538
C VARIABLE CONTOURS                                       A 540
C     ------------------------------------                A 542
          NCURES=0                                        A 544
          DO 30 I=1,NVCON                                 A 546
             CL=VCON(I)                                   A 548
             CV=CL                                        A 550
             CALL SCAN                                    A 552
30        CONTINUE                                        A 554
          GO TO 45                                        A 556
C                                                         A 558
C     ------------------------------------                A 560
C REGULAR CONTOURS                                        A 562
C     ------------------------------------                A 564
35        CV=CBGN                                         A 566
          NCURES=0                                        A 568
40        CL=CV                                           A 570
          CALL SCAN                                       A 572
          CV=CV+CINC                                      A 574
          IF (CV.LE.CEND) GO TO 40                        A 576
45        END FILE 3                                      A 578
          REWIND 3                                        A 580
          GO TO 10                                        A 582
C                                                         A 584
C     ------------------------------------                A 586
C NCOL=2,3,4                                              A 588
C DEFINE THETA FOR ROTATION                               A 590
C     ------------------------------------                A 592
50        IOP(NCOL)=1                                     A 594
          NROUND=1                                        A 596
          THETA=-TEMP(1)/57.295795                        A 598
          STHETA(NCOL)=SIN(THETA)                         A 600
          CTHETA(NCOL)=COS(THETA)                         A 602
          GO TO 10                                        A 604
C                                                         A 606
C     ------------------------------------                A 608
C NCOL=5                                                  A 610
C     ------------------------------------                A 612
55        IOP(NCOL)=1                                     A 614
          GO TO 10                                        A 616
C                                                         A 618
C     ------------------------------------                A 620
C NCOL=6                                                  A 622
C     ------------------------------------                A 624
60        IOP(NCOL)=1                                     A 626
          READ (5,260) (USER(I),I=1,8)                    A 628
          GO TO 10                                        A 630
```

```
C
C    ------------------------------------
C   NCODE = 7
C   LABEL CONTOURS
C    ------------------------------------
65     IOP(NCODE)=1
       CNUMB=TEMP(1)
       READ (5,255) DECI
       GO TO 10
C
C    ------------------------------------
C NCODE=8,9
C DEFINE PERSPECTIVE CONSTANTS
C    ------------------------------------
70     IOP(NCODE)=1
       IF (NCODE-8) 80,75,80
75     NBOUND=1
80     CONTINUE
       UP=TEMP(1)
       DO=TEMP(2)
       GO TO 10
C
C    ------------------------------------
C NCODE=10
C DEFINE TRANSLATION
C    ------------------------------------
85     DX(1)=TEMP(1)
       DY(1)=TEMP(2)
       DZ(1)=TEMP(3)
       IOP(NCODE)=1
       GO TO 10
C
C    ------------------------------------
C NCODE=11
C    ------------------------------------
90     ISTAR=TEMP(1)
       GO TO 10
C
C    ------------------------------------
C NCODE=12
C    ------------------------------------
95     IOP(12)=1
       TITCOD=TEMP(1)
       TITHT=TEMP(2)
       READ (5,260) (TIT(I),I=1,8)
       WRITE (6,265) (TIT(I),I=1,8)
       GO TO 10
C
C    ------------------------------------
C NCODE=13
C END PLOT TAPE
C    ------------------------------------
100    CALL PLOT (0,0,999)
       STOP
C
C    ------------------------------------
C NCODE=14
C READ LABELS AND THEIR CORRESPONDING COORDINATES
C    ------------------------------------
105    IOP(14)=1
       ILAB=ILAB+1
       XL(ILAB)=TEMP(1)
       YL(ILAB)=TEMP(2)
       IF (ZSCALE) 115,110,115
110    ZL(ILAB)=TEMP(3)
       GO TO 120
C
115    ZL(J)=TEMP(3)/ZSCALE
120    HT(ILAB)=TEMP(4)
       READ (5,270) (LAB(I,ILAB),I=1,6)
       GO TO 10
C
C    ------------------------------------
C NCODE=15
C DEFINE CONTOUR INCREMENTS
C    ------------------------------------
125    CBGN=TEMP(1)
       CINC=TEMP(2)
       CEND=TEMP(3)
       IOP(15)=1
       IOPV=0
       GO TO 10
```

```
C
C     ------------------------------------
C NCON=16
C     ------------------------------------
130    CHGN=TEMP(1)
       CINC=TEMP(2)
       CEND=TEMP(3)
       IOPV=0
       REWIND 3
       GO TO 35
C
C     ------------------------------------
C NCON=17
C     ------------------------------------
135    NVCON=TEMP(1)
       IOP(15)=1
       IOPV=1
       READ (5,260) (CFMT(I),I=1,8)
       READ (5,CFMT) (VCON(I),I=1,NVCON)
       GO TO 10
C
C     ------------------------------------
C     NCON=18
C     ------------------------------------
140    IOP(18)=1
       SIZE=TEMP(1)
       GO TO 10
C
C     ------------------------------------
C NCON=19
C READ FORMAT FOR MATRIX
C     ------------------------------------
145    READ (5,260) (FMT(I),I=1,8)
       IOP(19)=1
       GO TO 10
C
C     ------------------------------------
C NCON=20
C BEGIN PLOTTING
C     ------------------------------------
150    IF (IOP(20).EQ.1) GO TO 155
       IF (IOP(6).EQ.0) GO TO 215
       CALL PLOTS
       CALL SYMBOL (0.,0.,.2,USER,90.,80)
       CALL PLOT (1.,0.,-3)
       IOP(20)=1
155    IF (IOP(8).EQ.0) IOP(9)=1
       IF (IOP(18).EQ.0) GO TO 180
       XCEN=(MAXX+MINX)/2.
       YCEN=(MAXY+MINY)/2.
       YCEN1=YCEN
       XCEN1=XCEN
       IF (IOP(17).EQ.0) GO TO 160
       CHGN=VCON(1)
       CEND=VCON(NVCON)
160    IF (IOP(2).EQ.0) GO TO 165
       YCEN1=CTHETA(2)*YCEN-CHGN*STHETA(2)/7SCALE
       YCEN=CTHETA(2)*YCEN-CEND*STHETA(2)//ZSCALE
165    IF (IOP(3).EQ.3) GO TO 170
       XCEN1=CTHETA(3)*XCEN+CHGN*STHETA(3)//ZSCALE
       XCEN=CTHETA(3)*XCEN+CEND*STHETA(3)/ZSCALE
170    IF (IOP(3).EQ.0) GO TO 175
       XCEN1=CTHETA(4)*XCEN1-STHETA(4)*YCEN1
       XCEN=CTHETA(4)*XCEN-STHETA(4)*YCEN
175    XCEN=(XCEN1+XCEN)/2.
       XCEN=XCEN/SCALE+XMAX
       XMAX=XMAX-XCEN+SIZE/2.
180    IF (IOP(1).EQ.0) GO TO 230
C
C     ------------------------------------
C CALL DRAFT TO PLOT
C     ------------------------------------
       CHGO=-53139.E15
       NCURV=0
       NCOUNT=
       NCMAX=0
```

```
      IF (NLINES) 200,200,185
185   READ (3) N,CV
      IF (CHGN.EQ.-53139.E15) CHGN=CV/ZSCALE-.5
      READ (3) (X(I),Y(I),I=1,N)
      NCURV=NCURV+1
      NCOUNT=NCOUNT+N
      IF (N-NCMAX) 195,190,190
190   NCMAX=N
      CLMAX=CV
195   CV=CV/ZSCALE
      CALL DRAFT
      IF (NCURV-NLINES) 185,205,205
200   CHGN=0.
205   N=5
      CV=CHGN
      X(1)=FN1
      X(2)=-X(1)+1.
      X(3)=X(2)
      X(4)=X(1)
      X(5)=X(1)
      Y(1)=FN2
      Y(2)=Y(1)
      Y(3)=-Y(2)+1.
      Y(4)=Y(3)
      Y(5)=Y(1)
      CALL DRAFT
      XNEW=YMAX*2.
      CALL PLOT (XNEW,0.,-3)
      GO TO 10
C
C    ------------------------------------
C NCON=21
C CHANGE SCALE
C    ------------------------------------
210   SCALE=(FLOAT(M)-1.)/TEMP(1)
      GO TO 10
C
215   WRITE (6,275)
      GO TO 240
C
220   WRITE (6,280)
      GO TO 240
C
225   WRITE (6,285)
      GO TO 240
C
230   WRITE (6,290)
      GO TO 240
C
235   WRITE (6,295) NCON
240   WRITE (6,300)
      STOP
C
245   FORMAT (I2,6F10.0)
250   FORMAT (3X,I5,6F10.3)
255   FORMAT (A10)
260   FORMAT (8A10)
265   FORMAT (1H0,8A10)
270   FORMAT (6A6)
275   FORMAT (41H0****PLOT USER IDENTIFICATION NOT DEFINED)
280   FORMAT (32H0****FORMAT NOT DEFINED FOR DATA)
285   FORMAT (31H0****CONTOUR LEVELS NOT DEFINED)
290   FORMAT (12H0****NO DATA)
295   FORMAT (27H0****NCON NOT LEGAL, NCON =,I5)
300   FORMAT (20H0****PLOT TERMINATED)
      END
```

m) FORSTAT CROSS-REFERENCE LISTINGS FOR PROGRAM CONTUR

```
PROGRAM      CONTUR

 STATEMENT NUMBER    DEFINITION                                              REFERENCES

             5            16.                         15.
            10            18.                         62.    64.    70.    73.    77.    84.    89.    91.
                                                      97.   110.   116.   128.   131.   134.   195.   197.
            15            22.                         21.
            20            39.                         36.
            25            42.                         41.
            30            52.                         46.
            35            54.                         46.   122.
            40            56.                         59.
            45            60.                         53.
            50            63.                         21.
            55            69.                         21.
            60            71.                         21.
            65            74.                         21.
            70            78.                         21.
            75            80.                         79.
            80            81.                         79.
            85            85.                         21.
            90            90.                         21.
            95            92.                         21.
           100            98.                         21.
           105           100.                         21.
           110           105.                        104.
           115           107.                        104.
           120           108.                        106.
           125           111.                         21.
           130           117.                         21.
           135           123.                         21.
           140           129.                         21.
           145           132.                         21.
           150           135.                         21.
           155           141.                        135.
           160           150.                        147.
           165           153.                        150.
           170           156.                        153.
           175           159.                        156.
           180           162.                        142.
           185           168.                        167.   178.
           190           174.                        173.
           195           176.                        173.
           200           179.                        167.
           205           180.                        176.
           210           196.                         21.
           215           198.                        136.
           220           200.                         40.
           225           202.                         45.
           230           204.                        162.
           235           206.                         20.
           240           207.                        199.   201.   203.   205.
           245           209.          FORMAT         18.
           250           210.          FORMAT         19.
           255           211.          FORMAT         76.
           260           212.          FORMAT         72.    95.   126.   132.
           265           213.          FORMAT         96.
           270           214.          FORMAT        109.
           275           215.          FORMAT        198.
           280           216.          FORMAT        200.
           285           217.          FORMAT        202.
           290           218.          FORMAT        204.
           295           219.          FORMAT        206.
           300           220.          FORMAT        207.


 60  STATEMENT NUMBERS DEFINED

 16  MAXIMUM  NUMBER OF REFERENCES

 83  TOTAL    NUMBER OF REFERENCES

1.4  AVERAGE  NUMBER OF REFERENCES
```

```
PROGRAM     CONTUR

 LABEL      TYPE      DEFINITION                                   REFERENCES

AM          R            2. CD                 4.    42.    43.
CBGN        R           54.                  111.   117.   148.   151.   154.   163.   169.   179.   181.
CEND        R           59.                  113.   119.   149.   152.   155.
CFMT        R            2.  D               126.   127.
CINC        R           56.                  112.   116.
CL          R            4. C                 49.    50.    56.
CLMAX       R          175.
CNUMM       R            6. C                 75.
COS         R           67.        FUNCTION
CTHETA      R            2. CD                 4.    67.   151.   152.   154.   155.   157.   158.
CV          R            4. C                 50.    54.    56.    58.    59.   148.   169.   175.   176.   181.
D           R            4. C                 12.
DECI        R            6. C                 76.
DL          R            4. C
DO          R            4. C                 83.
DP          R            4. C                 82.
DRAFT       R          177.        SUBROUTINE 192.
DX          R            2. CD                 4.    85.
DY          R            2. CD                 4.    86.
DZ          R            2. CD                 4.    87.
EIS         R           34.                   35.   163.   169.
FLOAT       R           28.        FUNCTION   29.   196.
FMT         R            2.  D                42.    43.   132.
FM2         R            4. C                 28.    30.   167.
FNN         R            4. C                 29.    31.   162.
HT          R            2. CD                 4.   108.
I           I           15.                   16.    18.    19.    41.    42.    43.    48.    49.    72.    95.    96.   109.   126.   127.
                                             132.   170.
IDX         I            4. C
IDY         I            4. C
ILAB        I            4. C                 13.   101.   102.   103.   105.   108.   109.
INX         I            2. CD                 4.
INY         I            2. CD                 4.
IOP         I            2. CD                 4.     9.    16.    36.    37.    38.    39.    40.    45.    63.    69.    71.    74.    78.
                                              88.    92.   100.   114.   124.   129.   133.   135.   136.   140.   141.   142.   147.   150.
                                             153.   156.   162.
IOFV        I           46.                  115.   120.   125.
IPT         I            2. CD                 4.
ISS         I            4. C
ISTAP       I           11.        FILE       42.    90.
IT          I            4. C
IV          I            4. C
IX          I            4. C
IY          I            4. C
J           I           42.                   43.   107.
JT          I            4. C
LAB         I            2. CD                 4.   109.
M           I            4. C                 22.    28.    41.    43.   196.
MAXX        R            5. C                  7.    32.   143.
MAXY        R            5. C                  7.    33.   144.
```

```
MINX      R       5. C              7.  34. 143.
MINY      R       5. C              7.  35. 144.
MT        I       4. C
N         I       4. C            168. 170. 172. 173. 174. 180.
NBOUND    I      17.               64.  80.
NCMAX     I     166.              173. 174.
NCON      I      18.               19.  20.  21.  63.  66.  67.  69.  71.  74.  76.  79.  88. 206.
NCOUNT    I     165.              172.
NCURV     I       4. C            164. 171. 178.
NI        I       4. C
NLINES    I       4. C             10.  47.  55. 167. 178.
NN        I       4. C             23.  29.  42.  43.
NP        I       4. C
NPLOT     I       8.
NT        I       4. C
NVCON     I      48.              123. 127. 149.
PLOT      R      98.  SUBROUTINE  139. 194.
PLOTS     R     137.  SUBROUTINE
PY        R       4. C
REC       R       2. CD             4.
SCALE     R       4. C             25.  30.  31. 160. 196.
SCAN      R      51.  SUBROUTINE   57.
SIN       R      66.  FUNCTION
SIZE      R       5. C            130. 161.
STHETA    R       2. CD             4.  66. 151. 152. 154. 155. 157. 158.
SYMBOL    R     138.  SUBROUTINE
TEMP      R       2.  D            18.  19.  22.  23.  24.  25.  26.  27.  65.  75.  82.  83.  85.  86.
                                   87.  90.  93.  94. 102. 103. 105. 107. 108. 111. 112. 113. 117. 118.
                                  119. 123. 130. 196.
THETA     R      65.               66.  67.
TIT       R       2. CD             4.  95.  96.
TITCOD    R       6. C             93.
TITMT     R       6. C             94.
USER      R       3.  D            72. 138.
VCON      R       2.  D            49. 127. 148. 149.
WORK      R       2. CD             4.
X         R       2. CD             4. 170. 182. 183. 184. 185. 186.
XCEN      R     143.              146. 154. 155. 158. 159. 160. 161.
XCEN1     R     146.              154. 157. 159.
XL        R       2. CD             4. 102.
XMAX      R       4. C             31. 160. 161.
XNEW      R     193.              194.
Y         R       2. CD             4. 170. 187. 188. 189. 190. 191.
YCEN      R     144.              145. 151. 152. 158.
YCEN1     R     145.              151. 157.
YL        R       2. CD             4. 103.
YMAX      R       4. C             30. 193.
Z         R       2. CD             4.
ZL        R       2. CD             4. 105. 107.
ZSCALE    R       6. C             27. 104. 107. 151. 152. 154. 155. 169. 176.

 95 SYMBOLS DEFINED

 32 MAXIMUM NUMBER OF REFERENCES

310 TOTAL   NUMBER OF REFERENCES

3.3 AVERAGE NUMBER OF REFERENCES
```

n) LISTING OF SUBROUTINE SCAN

```
      SUBROUTINE SCAN
C     ------------------------------------------------------------------
C                             SUBROUTINE SCAN
C     ------------------------------------------------------------------
C
C     PURPOSE --
C          TO SCAN THE DATA AND LOCATE THE CONTOURS.
C
C     ------------------------------------------------------------------
C                        THE GCARS SYSTEM
C                        PURDUE UNIVERSITY
C
C                                                  A. KEITH TURNER,
C                                                  CIVIL ENGINEERING,
C                                                  JUNE 1969 .
C     ------------------------------------------------------------------
C
C     USAGE --
C          CALL SCAN
C
C     ------------------------------------------------------------------
C
C     DESCRIPTION OF CONTROL CARDS -
C          NONE REQUIRED - ALL NECESSARY PARAMETERS PASEED VIA BLANK COMM
C
C     ------------------------------------------------------------------
C
C     REQUIRED SUBROUTINES -
C          - TRACE
C          - CALC
C
C     OPTIONAL SUBROUTINES --
C          - NONE
C
C     ------------------------------------------------------------------
      DIMENSION AM(100,100), REC(800), X(1500), Y(1500), IPT(3,3), INX(8
     1), INY(8), IOP(20), AL(10), YL(10), ZL(10), LAB(10,6), DX(2), DY(2
     2), DZ(2), HT(10), CTHETA(4), STHETA(4), Z(1500), TIT(8), WORK(1024
     3)
      COMMON MI,NT,NI,IX,IY,IDX,IDY,ISS,IT,IV,NP,N,JT,PY,REC,CV,X,Y,IPT,
     1INX,INY,DL,AM,IOP,DP,DD,ILAB,AL,YL,ZL,LAB,DX,DY,DZ,AMAX,HT,SCALE,Y
     2MAX,CTHETA,STHETA,FM2,FNN,NN,M,CL,D,NLINES,NCURV,Z,TIT,WORK
      IZX=1
      NP=0
      DL=0
      NI=M
      MI=NN
      IF (IZX) 10,10,5
5     IPT(1,1)=8
      IPT(1,2)=1
      IPT(1,3)=2
      IPT(2,1)=7
      IPT(2,3)=3
      IPT(3,1)=6
      IPT(3,2)=5
      IPT(3,3)=4
      INX(1)=-1
      INX(2)=-1
      INX(3)=0
      INX(4)=1
      INX(5)=1
      INX(6)=1
      INX(7)=0
      INX(8)=-1
      INY(1)=0
      INY(2)=1
      INY(3)=1
      INY(4)=1
      INY(5)=0
      INY(6)=-1
      INY(7)=-1
      INY(8)=-1
      IZX=0
10    XI=MI
      DO 15 J=1,800
15    REC(J)=0.
      ISS=0
      MT1=MT-1                                    B 156
      DO 30 I=1,MT1                               B 158
         IF (AM(I,1)-CV) 20,30,30                 B 160
20       IF (AM(I+1,1)-CV) 30,25,25               B 162
25       IX=I+1                                   B 164
         IY=1                                     B 166
         IDX=-1                                   B 168
         IDY=0                                    B 170
         CALL TRACE                               B 172
30    CONTINUE                                    B 174
      NT1=NT-1                                    B 176
      DO 45 I=1,NT1                               B 178
         IF (AM(MT,I)-CV) 35,45,45                B 180
35       IF (AM(MT,I+1)-CV) 45,40,40              B 182
40       IX=MT                                    B 184
         IY=I+1                                   B 186
         IDX=0                                    B 188
         IDY=-1                                   B 190
         CALL TRACE                               B 192
45    CONTINUE                                    B 194
      DO 60 I=1,MT1                               B 196
         MT2=MT+1-I                               B 198
         IF (AM(MT2,NT)-CV) 50,60,60              B 200
50       IF (AM(MT2-1,NT)-CV) 60,55,55            B 202
55       IX=MT2-1                                 B 204
         IY=NT                                    B 206
         IDX=1                                    B 208
         IDY=0                                    B 210
         CALL TRACE                               B 212
60    CONTINUE                                    B 214
      DO 75 I=1,NT1                               B 216
         NT2=NT+1-I                               B 218
         IF (AM(1,NT2)-CV) 65,75,75               B 220
65       IF (AM(1,NT2-1)-CV) 75,70,70             B 222
70       IX=1                                     B 224
         IY=NT2-1                                 B 226
         IDX=0                                    B 228
         IDY=1                                    B 230
         CALL TRACE                               B 232
75    CONTINUE                                    B 234
      ISS=1                                       B 236
      NT1=NT-1                                    B 238
      MT1=MT-1                                    B 240
      DO 105 J=2,NT1                              B 242
      DO 105 I=1,MT1                              B 244
         IF (AM(I,J)-CV) 80,105,105               B 246
80       IF (AM(I+1,J)-CV) 105,85,85              B 248
85       COM=100*(I+1)+J                          B 250
         IF (NP) 90,100,90                        B 252
90       DO 95 ID=1,NP                            B 254
            IF (REC(ID)-COM) 95,105,95            B 256
95       CONTINUE                                 B 258
100      IX=I+1                                   B 260
         IY=J                                     B 262
         IDX=-1                                   B 264
         IDY=0                                    B 266
         CALL TRACE                               B 268
105   CONTINUE                                    B 270
      RETURN                                      B 272
      END                                         B 274-
```

o) FORSTAT CROSS-REFERENCE LISTINGS FOR SUBROUTINE SCAN

```
SUBROUTINE SCAN

STATEMENT NUMBER   DEFINITION                     REFERENCES

     [illegible]        17.          9.
       1                35.          9.
      15                37.         35.
       2                42.         41.
      25                43.         42.
       3                45.         40.    41.    42.
      35                52.         51.
      40                53.         52.
      45                55.         50.    51.    52.
      50                62.         61.
      55                63.         62.
       6                65.         59.    61.    62.
      65                72.         71.
      70                73.         72.
      75                78.         69.    71.    72.
      80                85.         84.
      85                86.         85.
       9                88.         87.
      95                90.         86.    89.
     100                91.         87.
     105                96.         82.    83.    84.    85.    89.

 21 STATEMENT NUMBERS DEFINED
  5 MAXIMUM NUMBER OF REFERENCES
 34 TOTAL NUMBER OF REFERENCES
1.6 AVERAGE NUMBER OF REFERENCES
```

```
SUBROUTINE SCAN

 LABEL      TYPE      DEFINITION                         REFERENCES

AM           R          2. CD          3.   41.   42.   51.   52.   61.   62.   71.   72.   84.   85.
CL           R          3. C
CUR          R         88.            89.
CTHETA       R          2. CD          3.
CV           R          3. C          41.   42.   51.   52.   61.   62.   71.   72.   84.   85.
D            R          3. C           6.
DL           R          3. C           6.
DU           R          3. C
DP           R          3. C
DX           R          2. CD          3.
DY           R          2. CD          3.
DZ           R          2. CD          3.
FM2          R          3. C
FNR          R          3. C
HT           R          2. CD          3.
I            I         40.            41.   42.   43.   50.   51.   52.   54.   59.   60.   69.   70.   83.   84.   85.
                                      86.   91.
ID           I         48.            49.
IDX          I          3. C          45.   55.   65.   75.   93.
IDY          I          3. C          46.   56.   66.   76.   94.
ILAB         I          3. C
INX          I          2. CD          3.   18.   19.   20.   21.   22.   23.   24.   25.
INY          I          2. CD          3.   26.   27.   28.   29.   30.   31.   32.   33.
IOP          I          2. CD          3.
IPT          I          2. CD          3.   10.   11.   12.   13.   14.   15.   16.   17.
ISS          I          3. C          36.   79.
IT           I          3. C
IV           I          3. C
IX           I          3. C          43.   53.   63.   73.   91.
IY           I          3. C          44.   54.   64.   74.   92.
IZX          I          4.             9.   34.
J            I         35.            37.   82.   84.   85.   86.   92.
JT           I          3. C
LAB          I          2. CD          3.
M            I          3. C           7.
MT           I          3. C           6.   35.   39.   51.   52.   53.   60.   81.
MT1          I         39.            40.   59.   61.   63.
MT2          I         60.            61.   62.   63.
N            I          3. C
NCURV        I          3. C
NI           I          3. C
NLINES       I          3. C
NN           I          3. C           8.
NP           I          3. C           5.   87.   88.
NT           I          3. C           7.   49.   61.   62.   64.   70.   80.
NT1          I         49.            50.   69.   [illegible]   82.
NT2          I         70.            71.   72.   74.
PY           R          3. C
REC          R          2. CD          3.   37.   49.
```

```
SCALE      R          3. C
STHETA     R          2. CD                  3.
TIT        R          2. CD                  3.
TRACE      R         47.        SUBROUTINE  57.    67.    77.    95.
WORK       R          2. CD                  3.
X          R          2. CD                  3.
XL         R          2. CD                  3.
XMAX       R          3. C
XT         R         35.
Y          R          2. CD                  3.
YL         R          2. CD                  3.
YMAX       R          3. C
Z          R          2. CD                  3.
ZL         R          2. CD                  3.
```

```
 62 SYMBOLS DEFINED
  16 MAXIMUM NUMBER OF REFERENCES
155 TOTAL    NUMBER OF REFERENCES
2.5 AVERAGE  NUMBER OF REFERENCES
```

p) LISTING OF SUBROUTINE TRACE

```
      SUBROUTINE TRACE
C     -----------------------------------------------------------------
C                              SUBROUTINE TRACE
C     -----------------------------------------------------------------
C
C     PURPOSE --
C          TO TRACE OUT EACH CONTOUR LINE IN TURN.
C
C     -----------------------------------------------------------------
C                    THE GCARS SYSTEM
C                    PURDUE UNIVERSITY
C
C                                                A. KEITH TURNER,
C                                                CIVIL ENGINEERING,
C                                                JUNE 1969 .
C     -----------------------------------------------------------------
C
C     USAGE --
C          CALL TRACE
C
C     -----------------------------------------------------------------
C
C     DESCRIPTION OF CONTROL CARDS -
C          NONE REQUIRED -ALL NECESSARY PARAMETERS PASSED VIA BLANK COMMON
C
C     -----------------------------------------------------------------
C
C     REQUIRED SUBROUTINES -
C          - CALC
C
C     OPTIONAL SUBROUTINES --
C          - NONE
C
C     -----------------------------------------------------------------
      DIMENSION AM(100,100), REC(800), X(1500), Y(1500), IPT(3,3), INX(8
     1), INY(8), IOP(20), XL(10), YL(10), ZL(10), LAB(10,6), DX(2), DY(2
     2), DZ(2), HT(10), CTHETA(4), STHETA(4), Z(1500), III(8), WORK(1024
     3)
      COMMON MI,NT,NI,IX,IY,IDX,IDY,ISS,IT,IV,NP,N,JT,PY,REC,CV,X,Y,IPT,
     1INX,INY,OL,AM,IOP,OP,OO,ILAB,XL,YL,ZL,LAB,DX,DY,DZ,AMAX,HT,SCALE,Y
     2MAX,CTHETA,STHETA,FM2,FNN,NN,M,CL,D,NLINES,NCURV,Z,III,WORK
      COMMON MAXX,MAXY,MINX,MINY,SIZE
      REAL MAXX,MAXY,MINX,MINY
      PY=0.0
      JT=0
      N=0
      IX0=IX
      IY0=IY
      ISX=IDX+2
      ISY=IDY+2
      IS=IPT(ISX,ISY)
      JTB=0
      IS0=IS
      IF (IS0-8) 10,10,5
    5 IS0=IS0-8
   10 II=0
   15 CALL CALC
      NZ=N
      N=NZ
      IF (IT+JT-1) 25,25,20
   20 XS=X(N-1)
      YS=Y(N-1)
      X(N-1)=X(N)
      Y(N-1)=Y(N)
      X(N)=XS
      Y(N)=YS
   25 IS=IS+1
      JT=IT
   30 IF (IS-9) 40,35,35
   35 IS=IS-8
   40 IDX=INX(IS)
      IDY=INY(IS)
      IX2=IX+IDX
      IY2=IY+IDY
      JTB=JTB+1
      IF (JTB-1500) 50,50,45
   45 WRITE (6,175) CV
      RETURN
```

```
50      IF (ISS) 75,75,55
55      IF (IX-IXO) 95,60,95
60      IF (IY-IYO) 95,65,95
65      IF (IS-150) 95,70,95
70      CALL CALC
        GO TO 150
C
75      IF (IX2) 80,140,80
80      IF (IX2-MI) 85,85,140
85      IF (IY2) 90,140,90
90      IF (IY2-NI) 95,95,140
95      IF (CV-AM(IX2,IY2)) 100,100,15
100     IF (IDX**2+IDY**2-1) 105,125,105
105     DCP=(AM(IX,IY)+AM(IX2,IY)+AM(IX,IY2)+AM(IX2,IY2))/4.0
        IF (DCP-CV) 15,110,110
110     IF (INX(IS-1)) 115,120,115
115     IX=IX+IDX
        IDX=-IDX
        PY=2.0
        CALL CALC
        IX=IX+IDX
        GO TO 125
C
120     IY=IY+IDY
        IDY=-IDY
        PY=2.0
        CALL CALC
        IY=IY+IDY
125     IF (AM(IX-1,IY)-CV) 130,135,135
130     NP=NP+1
        REC(NP)=100*IX+IY
135     IS=IS+5
        IX=IX2
        IY=IY2
        GO TO 30
C
140     XI=MI
        IF (AM(IX-1,IY)-CV) 145,150,150
145     NP=NP+1
        REC(NP)=100*IX+IY
150     NLINES=NLINES+1
        DO 155 K=1,N
           X(K)=X(K)-FM1
           Y(K)=Y(K)-FM2
155     CONTINUE
C
C   -------------------------------------
C STORE CURVE ON TAPE3
C   -------------------------------------
        IF (N) 170,170,160
160     WRITE (3) N,CL
        WRITE (3) (X(I),Y(I),I=1,N)
        WRITE (6,180) CV
        WRITE (6,185) (X(I),Y(I),I=1,N)
        IF (IOP(18).EQ.0) GO TO 170
        DO 165 I=1,N
           IF (X(I).GT.MAXX) MAXX=X(I)
           IF (Y(I).GT.MAXY) MAXY=Y(I)
           IF (X(I).LT.MINX) MINX=X(I)
165     IF (Y(I).LT.MINY) MINY=Y(I)
170     NE=-1
        RETURN
C
175     FORMAT (21H0 A CONTOUR AT LEVEL ,F6.2,16H WAS TERMINATED.)
180     FORMAT (16H0CONTOUR LEVEL =,F6.2)
185     FORMAT (2X,6F10.3)
        END
```

q) FORSTAT CROSS-REFERENCE LISTING FOR SUBROUTINE TRACE

```
SUBROUTINE TRACE

STATEMENT NUMBER   DEFINITION                REFERENCES

        5             17.                 16.
       10             18.                 16.
       15             19.                 51.   54.
       20             23.                 22.
       25             29.                 22.
       30             31.                 73.
       35             32.                 31.
       40             33.                 31.
       45             39.                 38.
       50             41.                 38.
       55             42.                 41.
       60             43.                 42.
       65             44.                 43.
       70             45.                 44.
       75             47.                 41.
       80             48.                 47.
       85             49.                 48.
       90             50.                 49.
       95             51.                 42.   43.   44.   50.
      100             52.                 51.
      105             53.                 52.
      110             55.                 54.
      115             56.                 55.
      120             62.                 55.
      125             67.                 52.   61.
      130             68.                 67.
      135             70.                 67.
      140             74.                 47.   48.   49.   50.
      145             76.                 75.
      150             78.                 46.   75.
      155             82.                 79.
      160             84.                 83.
      165             93.                 89.
      170             94.                 83.   88.
      175             96.      FORMAT     39.
      180             97.      FORMAT     86.
      185             98.      FORMAT     87.

 37 STATEMENT NUMBERS DEFINED

  4 MAXIMUM NUMBER OF REFERENCES

 47 TOTAL   NUMBER OF REFERENCES

1.3 AVERAGE NUMBER OF REFERENCES
```

```
SUBROUTINE TRACE

 LABEL       TYPE      DEFINITION                               REFERENCES

AM           P            2. CD                   3.   51.   53.   67.   75.
CALC         R           19.       SUBROUTINE    45.   59.   65.
CL           R            3. C                   84.
CTHETA       R            2. CD                   3.
CV           R            3. C                   39.   51.   54.   67.   75.   86.
D            R            3. C
OCF          R           53.                     54.
DL           R            3. C
DU           R            3. C
DP           R            3. C
DX           R            2. CD                   3.
DY           R            2. CD                   3.
DZ           R            2. CD                   3.
FM2          R            3. C                   81.
FNN          R            3. C                   80.
HT           R            2. CD                   3.
I            I           65.                     87.   89.   90.   91.   92.   93.
IDX          I            3. C                   11.   33.   35.   52.   56.   57.   60.
IDY          I            3. C                   12.   34.   36.   52.   62.   63.   66.
IL4B         I            3. C
INX          I            2. CD                   3.   33.   55.
INY          I            2. CD                   3.   34.
IOF          I            2. CD                   3.   88.
IP1          I            2. CD                   3.   13.
IS           I           13.                     15.   29.   31.   32.   33.   34.   44.   55.   70.
ISS          I            3. C                   41.
ISX          I           11.                     13.
ISY          I           12.                     13.
ISU          I           15.                     16.   17.   44.
IT           I            3. C                   18.   22.   30.
IV           I            3. C
IX           I            3. C                    9.   35.   42.   53.   56.   60.   67.   69.   71.   75.   77.
IXC          I            9.                     42.
IXP          I           35.                     47.   48.   51.   53.   71.
IY           I            3. C                   10.   36.   43.   53.   62.   66.   67.   69.   72.   75.   77.
IYC          I           10.                     43.
IYP          I           36.                     49.   50.   51.   53.   72.
JT           I            3. C                    7.   22.   30.
JTH          I           14.                     37.   38.
K            I           79.                     80.   81.
LAB          I            2. CD                   3.
M            I            3. C
MAXX         R            4. C                    5.   90.
MAXY         R            4. C                    5.   91.
MINX         R            4. C                    5.   92.
MINY         R            4. C                    5.   93.
MT           I            3. C                   48.   74.
N            I            3. C                    8.   20.   21.   23.   24.   25.   26.   27.   28.   79.   83.   84.   85.   87.
                                                 89.   94.
```

```
NCURV      I          3. C
NI         I          3. C
NLINES     I          3. C                   78.
NN         I          3. C
NP         I          3. C                   68.   69.   76.   77.
NT         I          3. C                   50.
NZ         I         20.                     21.
PY         R          3. C                    6.   58.   64.
REC        R          2. CD                   3.   69.   77.
SCALE      R          3. C
SIZE       R          4. C
STHETA     R          2. CD                   3.
TIT        R          2. CD                   3.
WORK       R          2. CD                   3.
X          R          2. CD                   3.   23.   25.   27.   80.   85.   87.   90.   92.
XL         R          2. CD                   3.
XMAX       R          3. C
XS         R         23.                     27.
XT         R         74.
Y          R          2. CD                   3.   24.   26.   28.   81.   85.   87.   91.   93.
YL         R          2. CD                   3.
YMAX       R          3. C
YS         R         24.                     28.
Z          R          2. CD                   3.
ZL         R          2. CD                   3.

 73 SYMBOLS DEFINED

 16 MAXIMUM NUMBER OF REFERENCES

178 TOTAL   NUMBER OF REFERENCES

2.4 AVERAGE NUMBER OF REFERENCES
```

r) LISTING OF SUBROUTINE CALC

```
      SUBROUTINE CALC
C     ------------------------------------------------------------------
C                                SUBROUTINE CALC
C     ------------------------------------------------------------------
C
C     PURPOSE --
C           TO PERFORM INTERPOLATIONS WITHIN DATA MATRIX SQUARES TO LOCATE
C     CONTOUR LINE COORDINATES.
C
C     ------------------------------------------------------------------
C                         THE GCARS SYSTEM
C                         PURDUE UNIVERSITY
C
C                                                A. KEITH TURNER,
C                                                CIVIL ENGINEERING,
C                                                JUNE 1969 .
C     ------------------------------------------------------------------
C
C     USAGE --
C           CALL CALC
C
C     ------------------------------------------------------------------
C
C     DESCRIPTION OF CONTROL CARDS -
C           NONE REQUIRED -ALL NECESSARY PARAMETERS PASSED VIA BLANK COMMON
C
C     ------------------------------------------------------------------
C
C     REQUIRED SUBROUTINES -
C           - NONE
C
C     OPTIONAL SUBROUTINES --
C           - NONE
C
C     ------------------------------------------------------------------
      DIMENSION AM(100,100), REC(800), X(1500), Y(1500), IPT(3,3), INX(8
     1), INY(8), IOP(20), XL(10), YL(10), ZL(10), LAB(10,6), DX(2), DY(2
     2), DZ(2), HT(10), CTHETA(4), STHETA(4), Z(1500), III(8), WORK(1024
     3)
      COMMON NT,NF,NI,IX,IY,IDX,IDY,ISS,II,IV,NP,N,JT,PY,REC,CV,X,Y,IPT,
     1INX,INY,DL,AM,IOP,DP,DO,ILAB,XL,YL,ZL,LAB,DX,DY,DZ,XMAX,HT,SCALE,Y
     2MAX,CTHETA,STHETA,FM2,FNN,EN,M,CL,D,NLINES,NCURV,Z,III,WORK
      II=0
      N=N+1
      IF (IDX**2+IDY**2-1) 20,5,20
5     IF (IDX) 15,10,15
10    X(N)=IX
      Z=IY
      IY2=IY+IDY
      DY=IDY
      Y(N)=((AM(IX,IY)-CV)/(AM(IX,IY)-AM(IX,IY2)))*DY+Z
      RETURN
15    Y(N)=IY
      W=IX
      DX=IDX
      IX2=IX+IDX
      X(N)=((AM(IX,IY)-CV)/(AM(IX,IY)-AM(IX2,IY)))*DX+W
      RETURN
20    IX2=IX+IDX
      IY2=IY+IDY
      W=IX
      Z=IY
      DX=IDX
      DY=IDY
      DCP=(AM(IX,IY)+AM(IX2,IY)+AM(IX,IY2)+AM(IX2,IY2))/4.0
      IF (PY-2.0) 25,30,25
25    IF (DCP-CV) 30,30,35
30    AL=AM(IX,IY)-DCP
      V=.5*(AL+DCP-CV)/AL
      X(N)=V*DX+W
      Y(N)=V*DY+Z
      PY=0.0
      RETURN
35    II=1
      AL=AM(IX2,IY2)-DCP
      V=.5*(AL+DCP-CV)/AL
      X(N)=-V*DX+W+DX
      Y(N)=-V*DY+Z+DY
      RETURN
      END
```

s) FORSTAT CROSS-REFERENCE LISTINGS FOR **SUBROUTINE CALC**

```
SUBROUTINE CALC

STATEMENT NUMBER   DEFINITION                        REFERENCES

      5               7.             6.
     10               8.             7.
     15              14.             7.
     2               20.             6.
     25              28.            27.
     30              29.            27.    28.
     35              35.            28.

  7 STATEMENT NUMBERS DEFINED
  2  MAXIMUM NUMBER OF REFERENCES
  8 TOTAL    NUMBER OF REFERENCES
1.1 AVERAGE NUMBER OF REFERENCES
```

```
SUBROUTINE CALC

 LABEL      TYPE      DEFINITION                                   REFERENCES

AL           R          29.             30.    35.    37.
AM           R           2.  CD          3.    12.    18.    20.    29.    36.
CL           R           3.  C
CTHETA       R           2.  CD          3.
CV           R           3.  C          12.    14.    28.    30.    37.
D            R           3.  C
DCP          R          26.             28.    29.    30.    36.    37.
DL           R           3.  C
DU           R           3.  C
DP           R           3.  C
DX           R           2.  CD          3.    16.    18.    24.    31.    38.
DY           R           2.  CD          3.    11.    12.    25.    32.    39.
DZ           R           2.  CD          3.
FM2          R           3.  C
FNN          R           3.  C
HI           R           2.  CD          3.
IDX          I           3.  C           6.     7.    16.    17.    20.    24.
IDY          I           3.  C           6.    10.    11.    21.    25.
ILAB         I           3.  C
INX          I           2.  CD          3.
INY          I           2.  CD          3.
IOP          I           2.  CD          3.
IPT          I           2.  CD          3.
ISS          I           3.  C
IT           I           3.  C           4.    35.
IV           I           3.  C
IX           I           3.  C           8.    12.    15.    17.    18.    20.    22.    26.    29.
IX2          I          17.             16.    20.    26.    36.
IY           I           3.  C           9.    10.    12.    14.    18.    21.    23.    26.    29.
IY2          I          10.             12.    21.    26.    36.
JT           I           3.  C
LAB          I           2.  CD          3.
M            I           3.  C
MT           I           3.  C
N            I           3.  C           5.     8.    12.    14.    18.    31.    32.    38.    39.
NCURV        I           3.  C
NI           I           3.  C
NLINES       I           3.  C
NN           I           3.  C
NP           I           3.  C
NT           I           3.  C
PY           R           3.  C          27.    33.
REC          R           2.  CD          3.
SCALE        R           3.  C
STHETA       R           2.  CD          3.
TIT          R           2.  CD          3.
V            R          31.             31.    32.    37.    38.    39.
W            R          15.             16.    22.    31.    36.
WORK         R           2.  CD          3.
X            R           2.  CD          3.     8.    18.    31.    38.
XL           R           2.  CD          3.
XMAX         R           3.  C
Y            R           2.  CD          3.    12.    14.    32.    39.
YL           R           2.  CD          3.
YMAX         R           3.  C
Z            R           2.  CD          3.     9.    12.    23.    32.    39.
ZL           R           2.  CD          3.

  57 SYMBOLS DEFINED

   9 MAXIMUM NUMBER OF REFERENCES

 121 TOTAL   NUMBER OF REFERENCES

 2.1 AVERAGE NUMBER OF REFERENCES
```

f) LISTING OF SUBROUTINE DRAFT

```
      SUBROUTINE DRAFT                                                  E   2
C     ----------------------------------------------------------------- E   4
C                             SUBROUTINE DRAFT                          E   6
C     ----------------------------------------------------------------- E   8
C                                                                       E  10
C     PURPOSE --                                                        E  12
C          TO PERFORM DESIRED TRANSLATIONS AND ROTATIONS. TO PREPARE PLOT E  14
C     TAPE USING CALCOMP ROUTINES.                                      E  16
C                                                                       E  18
C     ----------------------------------------------------------------- E  20
C                    THE GCARS SYSTEM                                   E  22
C                    PURDUE UNIVERSITY                                  E  24
C                                                                       E  26
C                                              A. KEITH TURNER,         E  28
C                                              CIVIL ENGINEERING,       E  30
C                                              JUNE 1969 .              E  32
C     ----------------------------------------------------------------- E  34
C                                                                       E  36
C     USAGE --                                                          E  38
C          CALL DRAFT                                                   E  40
C                                                                       E  42
C     ----------------------------------------------------------------- E  44
C                                                                       E  46
C     DESCRIPTION OF CONTROL CARDS -                                    E  48
C          NONE REQUIRED -ALL NECESSARY PARAMETERS PASSED VIA BLANK COMMON E  50
C                                                                       E  52
C     ----------------------------------------------------------------- E  54
C                                                                       E  56
C     REQUIRED SUBROUTINES -                                            E  58
C          - NONE                                                       E  60
C                                                                       E  62
C     OPTIONAL SUBROUTINES --                                           E  64
C          - PROJ                                                       E  66
C                                                                       E  68
C     ----------------------------------------------------------------- E  70
      DIMENSION AM(100,100), REC(800), X(1500), Y(1500), IPT(3,3), INX(8 E  72
     1), INY(8), IOP(20), XL(10), YL(10), ZL(10), LAB(10,6), DX(2), DY(2 E  74
     2), DZ(2), HT(10), CTHETA(4), STHETA(4), Z(1500), III(8), WORK(1024 E  76
     4)                                                                 E  78
      DIMENSION PART1(2)                                                E  80
      COMMON MI,ICT,NI,IA,IY,IDX,IDY,ISS,II,IV,NP,N,JT,PY,REC,CV,X,Y,IPT, E  82
     1INX,INY,DL,AM,IOP,DP,DO,ILAB,XL,YL,ZL,LAB,DX,DY,DZ,AMAX,HT,SCALE,Y E  84
     2MAX,CTHETA,STHETA,FM2,FNN,NN,M,CL,D,NLINES,NCURV,Z,III,WORK      E  86
      COMMON MAXX,MAXY,MINX,MINY,SIZE                                   E  88
      COMMON /SCALE,TITHT,CNUMH,DECI,TITCOD                             E  90
      REAL MAXX,MAXY,MINX,MINY                                          E  92
5     KTYPE=3                                                           E  94
      DO 105 I=2,14                                                     E  96
         IF (IOP(I)) 105,105,10                                         E  98
10       GO TO (15,15,20,25,105,105,105,40,40,95,105,105,105,70), I     E 100
C                                                                       E 102
C     -----------------------------------                               E 104
C ROTATION ABOUT X                                                      E 106
C     -----------------------------------                               E 108
15          D1=1.                                                       E 110
            D2=0.                                                       E 112
            D3=0.                                                       E 114
            D4=0.                                                       E 116
            D5=CTHETA(2)                                                E 118
            D8=STHETA(2)                                                E 120
            D7=0.                                                       E 122
            D6=-D8                                                      E 124
            D9=D5                                                       E 126
            GO TO 30                                                    E 128
C                                                                       E 130
```

```
C     ------------------------------------
C ROTATION ABOUT Y
C     ------------------------------------
20          D1=CTHETA(3)
            D2=0.
            D3=STHETA(3)
            D4=0.
            D5=1.
            D6=0.
            D7=-D3
            D8=0.
            D9=D1
            GO TO 30
C
C     ------------------------------------
C ROTATION  ABOUT  Z
C     ------------------------------------
25          D1=CTHETA(4)
            D4=STHETA(4)
            D3=0.
            D2=-D4
            D5=D1
            D6=0.
            D7=0.
            D8=0.
            D9=1.
C
C     ------------------------------------
C ROTATE
C     ------------------------------------
30          CVD3=CV*D3
            CVD6=CV*D6
            CVD9=CV*D9
            DO 35 J=1,N
               XX=D1*X(J)+D2*Y(J)+CVD3
               YY=D4*X(J)+D5*Y(J)+CVD6
               Z(J)=D7*X(J)+D8*Y(J)+CVD9
               X(J)=XX
35          Y(J)=YY
            GO TO 105
C
C     ------------------------------------
C PRINT HEADING INFORMATION
C     ------------------------------------
40          CONTINUE
            IF (I-8) 45,45,50
45          NN1=2
            WRITE (6,165) DP,DO
            GO TO 55
C
50          NN1=1
55          IF (IOP(12)) 60,65,60
60          CALL SYMBOL (TITCOD,3.,TITHT,TIT,90.,80)
65          IOP(8)=0
            IOP(9)=0
            GO TO 105
C
C     ------------------------------------
C  PLOT  LABEL  ON  GRAPH
C     ------------------------------------
70          DO 90 J=1,ILAB
               GO TO (80,75), NN1
75             E=(DO-ZL(J))/DP*SCALE
               F=(DO/DP)*SCALE
               C1=(XL(J)-FNN1)/E+XMAX
               C2=(YL(J)-FM2)/E+YMAX
               GO TO 85
C
80             C1=XL(J)/SCALE+XMAX
               C2=YL(J)/SCALE+YMAX
               E=SCALE
85             HT(J)=HT(J)/E
90          IOP(14)=0
            GO TO 105
C
```

```
C     ------------------------------------                              E 282
C TRANSLATE  DATA                                                       E 284
C     ------------------------------------                              E 286
95          DO 100 J=1,N                                                E 288
               X(J)=X(J)+DX(1)                                          E 290
               Y(J)=Y(J)+DY(1)                                          E 292
100         Z(J)=Z(J)+DZ(1)                                             E 294
C     ------------------------------------                              E 296
C PLOT PLANE OR PERSPECTIVE VIEW OF SURFACE                             E 298
C     ------------------------------------                              E 300
105     CONTINUE                                                        E 302
        IOPC=IOP(2)+IOP(3)+IOP(4)                                       E 304
        DO 155 J=1,N                                                    E 306
            IF (IOPC) 110,110,115                                       E 308
110         Z(J)=CV                                                     E 310
115         GO TO (120,125), NN                                         E 312
120         C1=X(J)/SCALE+XMAX                                          E 314
            C2=Y(J)/SCALE+YMAX                                          E 316
            GO TO 130                                                   E 318
C                                                                       E 320
125         E=(DD-Z(J))/DP*SCALE                                        E 322
            C1=X(J)/E+XMAX                                              E 324
            C2=Y(J)/E+YMAX                                              E 326
130         IF (IOP(5)) 140,140,135                                     E 328
135         CALL PROJ (C1,C2)                                           E 330
140         IF (C1.GT.SIZE.OR.C1.LT.-1.) GO TO 150                      E 332
            CALL PLOT (C2,C1,KTYPE)                                     E 334
            IF (KTYPE.EQ.2) GO TO 145                                   E 336
            IF (IOP(7).EQ.0) GO TO 145                                  E 338
            CVV=CV*/SCALE                                               E 340
            CALL NUMBER (C2,C1,CNUMB,CVV,90.,DECI)                      E 342
            CALL PLOT (C2,C1,3)                                         E 344
            CH1=C1                                                      E 346
            CH2=C2                                                      E 348
145         KTYPE=2                                                     E 350
            GO TO 155                                                   E 352
C                                                                       E 354
150         KTYPE=3                                                     E 356
155     CONTINUE                                                        E 358
        IF (IOP(7).EQ.0) GO TO 160                                      E 360
        IF (CH2.EQ.C2.AND.CH1.EQ.C1) GO TO 160                          E 362
        CALL NUMBER (C2,C1,CNUMB,CVV,90.,DECI)                          E 364
160     CONTINUE                                                        E 366
        RETURN                                                          E 368
C                                                                       E 370
165     FORMAT (24H0    DISTANCE TO PLANE =,F9.2,22H, DISTANCE TO OBJECT =    E 372
       1,F9.2)                                                          E 374
        END                                                             E 376-
```

u) FORSTAT CROSS-REFERENCE LISTINGS FOR SUBROUTINE DRAFT

```
SUBROUTINE DRAFT

STATEMENT NUMBER   DEFINITION                          REFERENCES

        5               8.
       10              11.                  10.
       15              12.                  11.
       20              22.                  11.
       25              32.                  11.
       30              41.                  21.   31.
       35              49.                  44.
       40              51.                  11.
       45              53.                  52.
       50              56.                  52.
       55              57.                  55.
       60              58.                  57.
       65              59.                  57.
       70              62.                  11.
       75              64.                  63.
       80              69.                  63.
       85              72.                  68.
       90              73.                  62.
       95              75.                  11.
      100              78.                  75.
      105              79.                   9.   10.   10.   11.   50.   61.   74.
      110              83.                  82.
      115              84.                  82.
      120              85.                  84.
      125              88.                  84.
      130              91.                  87.
      135              92.                  91.
      140              93.                  91.
      145             102.                  95.   96.
      150             104.                  93.
      155             105.                  81.  103.
      160             109.                 106.  107.
      165             111.       FORMAT     54.
```

```
 33 STATEMENT NUMBERS DEFINED

  7 MAXIMUM NUMBER OF REFERENCES

 42 TOTAL   NUMBER OF REFERENCES

1.3 AVERAGE NUMBER OF REFERENCES
```

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SUBROUTINE DRAFT

 LABEL      TYPE      DEFINITION                         REFERENCES

AM           R           2. CD          4.
CM1          R         100.           107.
CM2          R         101.           107.
CL           R           4. C
CNUMH        R           6. C          96.  108.
CTHETA       R           2. CD          4.   16.   22.   32.
CV           R           4. C          41.   42.   43.   83.   97.
CVD3         R          41.            45.
CVD6         R          42.            46.
CVD9         R          43.            47.
CVV          R          97.            98.  106.
C1           R          66.            69.   85.   89.   92.   93.   94.   96.   99.  100.  107.  108.
C2           R          67.            70.   86.   90.   92.   94.   96.   99.  101.  107.  108.
D            R           4. C
DECI         R           6. C          98.  106.
DL           R           4. C
DO           R           4. C          54.   64.   65.   88.
DP           R           4. C          54.   64.   65.   88.
DX           R           2. CD          4.   76.
DY           R           2. CD          4.   77.
DZ           R           2. CD          4.   78.
D1           R          12.            22.   30.   32.   36.   45.
D2           R          13.            23.   35.   45.
D3           R          14.            24.   28.   34.   41.
D4           R          15.            25.   33.   35.   46.
D5           R          16.            20.   26.   36.   46.
D6           R          19.            27.   37.   42.
D7           R          18.            26.   38.   47.
D8           R          17.            19.   29.   39.   47.
D9           R          20.            30.   40.   43.
E            R          64.            66.   67.   88.   89.   90.
F            R          65.            71.   72.
FM2          R           4. C          67.
FNN          R           4. C          66.
HT           R           2. CD          4.   72.
I            I           9.            10.   11.   52.
IDX          I           4. C
IDY          I           4. C
ILAM         I           4. C          62.
INX          I           2. CD          4.
INY          I           2. CD          4.
IOP          I           2. CD          4.   10.   57.   59.   60.   73.   80.   91.   96.  106.
IOPC         I          80.            82.
IPT          I           2. CD          4.
ISS          I           4. C
IT           I           4. C
IV           I           4. C
IX           I           4. C
IY           I           4. C
J            I          44.            45.   46.   47.   48.   49.   62.   64.   66.   67.   69.   70.   72.   75.   76.
                                       77.   78.   81.   83.   85.   86.   88.   89.   90.
```

```
JT        I        4. C
KTYPE     I        8.                      94.   95.  102.  104.
LAB       I        2. CD                    4.
M         I        4. C
MAXX      R        5. C                     7.
MAXY      R        5. C                     7.
MINX      R        5. C                     7.
MINY      R        5. C                     7.
MT        I        4. C
N         I        4. C                    44.   75.   81.
NCURV     I        4. C
NI        I        4. C
NLINES    I        4. C
NN        I        4. C
NN1       I       53.                      50.   63.   84.
NP        I        4. C
NT        I        4. C
NUMBER    I       94.        SUBROUTINE  106.
PARTI     R        3.  D
PLOT      R       98.        SUBROUTINE   99.
PRO       R       92.        SUBROUTINE
PY        R        4. C
REC       R        2. CD                    4.
SCALE     R        4. C                    64.   65.   69.   70.   71.   85.   86.   88.
SIZE      R        5. C                    93.
STHETA    R        2. CD                    4.   17.   24.   33.
SYMBOL    R       58.        SUBROUTINE
TIT       R        2. CD                    4.   59.
TITCOD    R        6. C                    56.
TITHT     R        6. C                    56.
WORK      R        2. CD                    4.
X         R        2. CD                    4.   45.   46.   47.   48.   76.   85.   86.
XL        R        2. CD                    4.   64.   69.
XMAX      R        4. C                    66.   69.   85.   89.
XX        R       45.                      46.
Y         R        2. CD                    4.   45.   46.   47.   49.   77.   86.   90.
YL        R        2. CD                    4.   67.   77.
YMAX      R        4. C                    67.   70.   88.   90.
YY        R       45.                      49.
Z         R        2. CD                    4.   47.   78.   83.   88.
ZL        R        2. CD                    4.   64.
ZSCALE    R        6. C                    97.

 92 SYMBOLS DEFINED
 23 MAXIMUM NUMBER OF REFERENCES
217 TOTAL   NUMBER OF REFERENCES
2.4 AVERAGE NUMBER OF REFERENCES
```

v) LISTING OF SUBROUTINE PROJ

```
1.          SUBROUTINE PROJ (X,Y)                                                     F   2
        C   ---------------------------------------------------------------------    F   4
        C                            SUBROUTINE PROJ                                  F   6
        C   ---------------------------------------------------------------------    F   8
        C                                                                             F  10
        C   PURPOSE --                                                                F  12
        C        TO PROVIDE FOR ADDITIONAL OPTIONS TO BE DEVELOPED BY THE USER.       F  14
        C                                                                             F  16
        C   ---------------------------------------------------------------------    F  18
        C                  THE GCARS SYSTEM                                           F  20
        C                  PURDUE UNIVERSITY                                          F  22
        C                                                                             F  24
        C                                                 J. KEITH TURNER,            F  26
        C                                                 CIVIL ENGINEERING,          F  28
        C                                                 JUNE 1969 .                 F  30
        C   ---------------------------------------------------------------------    F  32
        C                                                                             F  34
        C   USAGE --                                                                  F  36
        C        CALL PROJ (X,Y)                                                      F  38
        C        WHERE-                                                               F  40
        C             X = X-COORDINATE OF CURRENT POINT                               F  42
        C             Y = Y-COORDINATE OF CURRENT POINT                               F  44
        C                                                                             F  46
        C   ---------------------------------------------------------------------    F  48
        C                                                                             F  50
        C   DESCRIPTION OF CONTROL CARDS -                                            F  52
        C        NONE REQUIRED -ALL NECESSARY PARAMETERS PASSED VIA BLANK COMMON      F  54
        C                                                                             F  56
        C   ---------------------------------------------------------------------    F  58
        C                                                                             F  60
        C   REQUIRED SUBROUTINES -                                                    F  62
        C        - NONE                                                               F  64
        C                                                                             F  66
        C   OPTIONAL SUBROUTINES --                                                   F  68
        C        - NONE                                                               F  70
        C                                                                             F  72
        C   ---------------------------------------------------------------------    F  74
2.          RETURN                                                                    F  76
3.          END                                                                       F  78-
***EOF***
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w) FORSTAT CROSS-REFERENCE LISTING FOR SUBROUTINE POLY

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 SUBROUTINE PROJ

 LABEL      TYPE      DEFINITION                                   REFERENCES

 X           R           1.
 Y           R           1.



       2 SYMBOLS DEFINED

       0 MAXIMUM NUMBER OF REFERENCES

       0 TOTAL   NUMBER OF REFERENCES

     0.0 AVERAGE NUMBER OF REFERENCES
```

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